| AD NUMBER |
| --- |
| **ADB129570** |
| LIMITATION CHANGES |
| TO:<br>**Approved for public release; distribution is unlimited.** |
| FROM:<br>**Distribution authorized to U.S. Gov't. agencies and their contractors; Critical Technology; MAR 1988. Other requests shall be referred to Air Force Armament Laboratory, Attn: FXG, Eglin Air Force Base, Florida 32542-5434. This document contains export-controlled technical data.** |
| AUTHORITY |
| **AFSC ltr, 13 Feb 1992** |

DTIC FILE COPY e901826

AFATL-TR-88-62, VOL III

# Common Ada Missile Packages—Phase 2 (CAMP-2)

## Volume III. CAMP Armonics Benchmarks

S Cohen
T Taylor

AD-B129 570

McDONNELL DOUGLAS ASTRONAUTICS COMPANY
P O BOX 516
ST LOUIS, MO 63166

DTIC ELECTE DEC 1 2 1988 S D E

NOVEMBER 1988

FINAL REPORT FOR PERIOD SEPTEMBER 1985-MARCH 1988

CRITICAL TECHNOLOGY

Distribution authorized to U.S. Government agencies and their contractors only; ~~this report documents test and evaluation~~; distribution limitation applied March 1988. Other requests for this document must be referred to the Air Force Armament Laboratory (FXG) Eglin Air Force Base, Florida 32542-5434.

DESTRUCTION NOTICE - For classified documents, follow the procedures in DoD 5220.22-M, Industrial Security Manual, Section II-19 or DoD 5200.1-R, Information Security Program Regulation, Chapter IX. For unclassified, limited documents, destroy by any method that will prevent disclosure of contents or reconstruction of the document.

AIR FORCE ARMAMENT LABORATORY

Air Force Systems Command ▪ United States Air Force ▪ Eglin Air Force Base, Florida

88 12 12 013

NOTICE

When Government drawings, specifications, or other data are used for any purpose other than in connection with a definitely Government-related procurement, the United States Government incurs no responsibility or any obligation whatsoever. The fact that the Government may have formulated or in any way supplied the said drawings, specifications, or other data, is not to be regarded by implication, or otherwise as in any manner construed, as licensing the holder, or any other person or corporation; or as conveying any rights or permission to manufacture, use, or sell any patented invention that may in any way be related thereto.

This report has been reviewed and is approved for publication.

FOR THE COMMANDER

Stephen C. Korn

STEPHEN C. KORN
Chief, Aeromechanics Division

Even though this report may contain special release rights held by the controlling office, please do not request copies from the Air Force Armament Laboratory. If you qualify as a recipient, release approval will be obtained from the originating activity by DTIC. Address your request for additional copies to:

Defense Technical Information Center
Cameron Station
Alexandria, VA 22304-6145

If your address has changed, if you wish to be removed from our mailing list, or if your organization no longer employs the addressee, please notify AFATL/FXG, Eglin AFB, FL 32542-5434, to help us maintain a current mailing list.

Do not return copies of this report unless contractual obligations or notice on a specific document requires that it be returned.

UNCLASSIFIED

SECURITY CLASSIFICATION OF THIS PAGE

# REPORT DOCUMENTATION PAGE

*Form Approved OMB No. 0704-0188*

| | |
|---|---|
| **1a. REPORT SECURITY CLASSIFICATION** UNCLASSIFIED | **1b. RESTRICTIVE MARKINGS** CRITICAL TECHNOLOGY |
| **2a. SECURITY CLASSIFICATION AUTHORITY** | **3. DISTRIBUTION/AVAILABILITY OF REPORT** Distribution authorized to U.S. Government Agencies and their contractors; ~~this report contains test and evaluation~~ (OVER) |
| **2b. DECLASSIFICATION/DOWNGRADING SCHEDULE** | |
| **4. PERFORMING ORGANIZATION REPORT NUMBER(S)** | **5. MONITORING ORGANIZATION REPORT NUMBER(S)** AFATL-TR-88-62, Volume III |
| **6a. NAME OF PERFORMING ORGANIZATION** McDonnell Douglas Astronautics Company<br>**6b. OFFICE SYMBOL** *(If applicable)* | **7a. NAME OF MONITORING ORGANIZATION** Aeromechanics Division<br>Guidance and Control Branch |
| **6c. ADDRESS (City, State, and ZIP Code)** P.O. Box 516<br>St Louis MO 63166 | **7b. ADDRESS (City, State, and ZIP Code)** Air Force Armament Laboratory<br>Eglin Air Force Base, Florida 32542-5434 |
| **8a. NAME OF FUNDING/SPONSORING ORGANIZATION** STARS Joint Program Office<br>**8b. OFFICE SYMBOL** *(If applicable)* | **9. PROCUREMENT INSTRUMENT IDENTIFICATION NUMBER** F08635-86-C-0025 |
| **8c. ADDRESS (City, State, and ZIP Code)** Room 3D139 (1211 Fern St)<br>The Pentagon<br>Washington DC 20301-3081 | **10. SOURCE OF FUNDING NUMBERS**<br>PROGRAM ELEMENT NO.: 63756D<br>PROJECT NO.: 921D<br>TASK NO: GT<br>WORK UNIT ACCESSION NO.: 02 |

**11. TITLE** *(Include Security Classification)* Common Ada Missile Packages-Phase 2 (CAMP-2), Volume III: CAMP Armonics Benchmarks

**12. PERSONAL AUTHOR(S)**
S. Cohen and T. Taylor

| 13a. TYPE OF REPORT | 13b. TIME COVERED | 14. DATE OF REPORT (Year, Month, Day) | 15. PAGE COUNT |
|---|---|---|---|
| Final | FROM Sep 85 TO Mar 88 | November 1988 | 70 |

**16. SUPPLEMENTARY NOTATION**

Availability of this report is specified on verso of front cover. (OVER)

| 17. COSATI CODES | | | 18. SUBJECT TERMS (Continue on reverse if necessary and identify by block number) |
|---|---|---|---|
| FIELD | GROUP | SUB-GROUP | Reusable Software, Missile Software, Software Generators, Ada parts, Composition, Systems, Software Parts |
| | | | |
| | | | |

**19. ABSTRACT** *(Continue on reverse if necessary and identify by block number)*


The CAMP project, primarily funded ty the STARS Joint Program Office, sponsored by the Air Force Armament Laboratory, and performed by McDonnell Douglas, has taken a pragmatic approach to demonstrating the feasibility and utility of the concept of software reuse for real-time embedded missile systems. CAMP products include: 452 operational flight software parts in Ada for tactical missiles, and a prototype parts engineering system to support parts identification, cataloging and construction. In order to demonstrate the value of the reuse concept, a missile subsystem was built using the CAMP parts. Results indicate a significant increase in software productivity when developing systems using parts, Ada, modern software engineering practice, robust software tools, and knowledgeable software engineers.

This report is documented in three volumes: Volume I - CAMP Parts and Parts Composition System, Volume II - 11th Missile Demonstration, and Volume III - CAMP Armonics Benchmarks.


| | |
|---|---|
| **20. DISTRIBUTION/AVAILABILITY OF ABSTRACT** ☐ UNCLASSIFIED/UNLIMITED ☒ SAME AS RPT. ☐ DTIC USERS | **21. ABSTRACT SECURITY CLASSIFICATION** UNCLASSIFIED |
| **22a. NAME OF RESPONSIBLE INDIVIDUAL** Christine M. Anderson | **22b. TELEPHONE** *(Include Area Code)* (904) 882-2961 — **22c. OFFICE SYMBOL** AFATL/FXG |

3. DISTRIBUTION/AVAILABILITY OF REPORT (CONCLUDED)

distribution limitation applied March 1988. Other requests for this document must be referred to the Air Force Armament Laboratory (FXG), Eglin Air Force Base, Florida 32542-5434.

16. SUPPLEMENTARY NOTATION (CONCLUDED)

## TRADEMARKS

**The following table lists the trademarks used throughout this document:**

| TRADEMARK | TRADEMARK OF |
|---|---|
| ACT | Advanced Computer Techniques |
| ART | Inference Corporation |
| ART Studio | Inference Corporation |
| CMS | Digital Equipment Corporation |
| DEC | Digital Equipment Corporation |
| Mikros | Mikros, Inc. |
| Oracle | Oracle Corporation |
| Scribe | Scribe Systems |
| Symbolics | Symbolics, Inc. |
| Symbolics 3620 | Symbolics, Inc. |
| TLD | TLD Systems Ltd |
| VAX | Digital Equipment Corporation |
| VMS | Digital Equipment Corporation |

# PREFACE

This report describes the work performed, the results obtained, and the conclusions reached during the Common Ada Missile Packages Phase-2 (CAMP-2) contract (F08635-86-C-0025). This work was performed by the Software and Information Systems Department of the McDonnell Douglas Astronautics Company, St. Louis, Missouri (MDAC-STL), and was sponsored by the United States Air Force Armament Laboratory (FXG) at Eglin Air Force Base, Florida. This contract was performed between September 1985, and March 1988.

The MDAC-STL CAMP program manager was:


Dr. Daniel G. McNicholl
Technology Branch
Software and Information Systems Department
McDonnell Douglas Astronautics Company
P.O. Box 516
St. Louis, Missouri 63166


The AFATL CAMP program manager was:


Christine M. Anderson
Guidance and Control Branch
Aeromechanics Division
Air Force Armament Laboratory
Eglin Air Force Base, Florida 32542-5434


This report consists of three volumes. Volume I contains information on the development of the CAMP parts and the Parts Composition System. Volume II contains the results of the 11th Missile Application development. Volume III contains the results of the CAMP Armonics Benchmarks Suite development.

Commercial hardware and software products mentioned in this report are sometimes identified by manufacturer or brand name. Such mention is necessary for an understanding of the R & D effort, but does not constitute endorsement of these items by the U.S. Government.

# ACKNOWLEDGEMENT


Special thanks to the Armament Division Deputy for Armament Control Office; to the Software Technology for Adaptable, Reliable Systems (STARS) Joint Program Office; to the Ada Joint Program Office (AJPO); and to the Air Force Electronic Systems Division, Computer Resource Management Technology Program Office for their support of this project.

# TRADEMARKS

The following table lists the trademarks used throughout this document:

| TRADEMARK | TRADEMARK OF |
|---|---|
| ACT | Advanced Computer Techniques |
| ART | Inference Corporation |
| ART Studio | Inference Corporation |
| CMS | Digital Equipment Corporation |
| DEC | Digital Equipment Corporation |
| Mikros | Mikros, Inc. |
| Oracle | Oracle Corporation |
| Scribe | Scribe Systems |
| Symbolics | Symbolics, Inc. |
| Symbolics 3620 | Symbolics, Inc. |
| TLD | TLD Systems Ltd |
| VAX | Digital Equipment Corporation |
| VMS | Digital Equipment Corporation |

## Table of Contents

## Table of Contents (CONCLUDED)

# List of Figures

# List of Tables

# List of Acronyms

| | |
|---|---|
| ACS | Ada Compilation System |
| ACVC | Ada Compiler Validation Capability |
| AdaJUG | Ada/Jovial Users Group |
| ADL | Ada Design Language |
| AFATL | Air Force Armament Laboratory |
| AFB | Air Force Base |
| AI | Artificial Intelligence |
| AJPO | Ada Joint Program Office |
| AMPEE | Ada Missile Parts Engineering Expert (System) |
| AMRAAM | Advanced Medium Range Air-to-Air Missile |
| ANSI | American National Standards Institude |
| APSE | Ada Programming Support Environment |
| Armonics | Armament Electronics |
| ART | Automated Reasoning Tool |
| ASCII | American Standard Code for Information Interchange |
| BC | Bus Controller |
| BDT | Basic Data Types |
| BIM | Bus Interface Module |
| CAD/CAM | Computer-Aid Design/Computer-Aided Manufacturing |
| CAMP | Common Ada Missile Packages |
| CCCB | Configuration Change Control Board |
| CDRL | Contractual Data Requirements List |
| CMS | Code Management System |
| ConvFactors | Conversion_Factors (TLCSC) |
| CPDS | Computer Program Development Specification |
| CPPS | Computer Program Product Specification |
| CSC | Computer Software Component |
| CSCI | Computer Software Configuration Item |
| CVMA | Coordinate_Vector_Matrix_Algebra (TLCSC) |
| DACS | Defense Analysis Center for Software |
| DBMS | Data Base Management System |
| DCL | DIGITAL Command Language |
| DDD | Detailed Design Document |
| DEC | Digital Equipment Corporation |
| DMA | Direct Memory Access |
| DoD | Department of Defense |

| | |
|---|---|
| DoD-STD | Department of Defense Standard |
| DPSS | Digital Processing Subsystem |
| DSR | Digital Standard Runoff |
| DTM | DEC /Test Manager |
| FMS | Forms Management System |
| FORTRAN | FORmula TRANslation |
| GPMath | General_Purpose_Math (TLCSC) |
| HOL | Higher-Order Language |
| Hr | Hour |
| I/O | Input/Output |
| ISA | Inertial Sensor Assembly |
| JOVIAL | Jules Own Version of International Algebraic Language |
| LISP | List Processing (language) |
| LLCSC | Lower Level Computer Software Component |
| LOC | Lines of Code |
| MDAC | McDonnell Douglas Astronautics Company |
| MDAC-HB | McDonnell Douglas Astronautics Company - Huntington Beach |
| MDAC-STL | McDonnell Douglas Astronautics Company - St. Louis |
| MDC | McDonnell Douglas Corporation |
| MIL-STD | Military Standard |
| MRASM | Medium Range Air-to-Surface Missile |
| NM | Nautical Miles |
| NPNav | North_Pointing_Navigation_Parts (TLCSC) |
| OCU | Operator Control Unit |
| Opns | Operations |
| PC | Personal Computer |
| PCS | Parts Composition System |
| PDL | Program Design Language |
| R&D | Research and Development |
| RT | Remote Terminal |
| RTE | Real-Time Embedded |
| SDF | Software Development File |
| SDI | Strategic Defense Initiative |
| SDN | Software Development Notebook |
| SDR | Software Discrepancy Report |
| SEAFAC | System Engineering Avionics Facility |
| SEI | Software Engineering Institute |

| | |
|---|---|
| SEP/SCP | Software Enhancement Proposal/Software Change Proposal |
| SIGAda | Special Interest Group on Ada |
| SRS | Software Requirements Specification |
| STARS | Software Technology for Adaptable, Reliable Systems |
| stmt | statement |
| SURMOS | Start-Up Real-time Multi-tasking Operating System |
| TLCSC | Top-Level Computer Software Component |
| TLDD | Top-Level Design Document |
| UnivConst | Universal_Constants (TLCSC) |
| VAX | Virtual Address Extension |
| VMS | Virtual Memory System |
| WGS72 | World Geodetic System, 1972 |

# SECTION I

# INTRODUCTION

## 1. IDENTIFICATION

The CAMP Armonics Benchmark Suite facilitates the evaluation of Ada software engineering environments and microprocessors intended for use in armonics[1] applications. The suite features both compilation and execution benchmarks to measure the capabilities of compiler/run-time systems. All benchmarks in this suite are portable and will permit comparisons to be made between widely different Ada systems.

This volume identifies the benchmarks and benchmark drivers, and suggests techniques for applying the Benchmark Suite. In addition, the structure, purpose, and methodology of the suite are explained to familiarize readers with the suite and to facilitate the evaluation of the suite by engineers. For those interested in using the benchmarks, a guide is provided in Section V. Appendix A contains data collected in the process of running the Benchmark Suite.

## 2. SYSTEM OVERVIEW

This Armonics Benchmark Suite serves a dual purpose: it offers a means for assessing the performance of CAMP parts and, at the same time, provides support for evaluating the suitability of compiler systems and their target machines to armonics applications.

Ada compiler performance is tested by a series of compilations, based on CAMP packages, which require a compiler to process complex uses of Ada generic units. These advanced (but standard) Ada features are used heavily in the CAMP parts and are central to the development and use of reusable software.

Other benchmarks of the suite are targeted primarily at run-time performance issues such as storage requirements, execution time, and computational accuracy. These benchmarks consist of a selection of CAMP parts which have been chosen as representative of the needs of armonics applications. Testing, using these benchmarks, is facilitated by embedding the benchmarks within portable drivers, written in Ada. Effectively, this allows the benchmarks to run themselves.

The Benchmark Suite can support a number of benchmarking scenarios:

- A project wishes to evaluate compilers for use in the development of a reusable parts library. The suite provides test code for evaluating compiler/linker systems.
- A compiler developer wants to measure the performance of his compiler/run-time system against an established standard. A group of benchmarks documented in this volume provides a standard for comparison between different systems.

[1] armament electronics

- An armonics application needs data on the memory utilization and timing efficiency of several compilers in order to select an appropriate compiler for a new project. The benchmarks provide opportunities for measuring these features of a given compiler.

- A potential user of CAMP parts wants specific performance data on the parts. The Benchmark Suite gives a user the ability to measure performance for a selected group of parts on varying architectures.

- A scientific application requires transcendental functions of known accuracy on a specific system and is considering the CAMP polynomial parts. The benchmarks supply data on the scientific functions of the CAMP Polynomials package.

The Benchmark Suite is supplemented by a set of procedures, encoded in DEC VAX Digital Command Language (DCL). By performing these procedures (or their equivalents on other operating systems), an engineer may install, compile, and run the various benchmarks efficiently. Details on the use of the Benchmark Suite and its command procedure environment are discussed in Section V.

## 3. VOLUME OVERVIEW

This report contains five main sections:

1. Introduction: Introduces the CAMP Benchmark Suite and this volume.

2. Benchmark Definitions: Explains the system of classes and levels by which the benchmarks are characterized. This section also introduces key terms and gives a tabular summary of benchmarks contained in the suite.

3. Purpose and Design: Discusses the procedure used to run each of the benchmarks and gives information about their structure and scope. For each benchmark, this section provides the following information where applicable:
   - Benchmark name
   - Compilation structure
   - Benchmark driver design
   - Benchmark inputs
   - Benchmark correct outputs
   - Data to be recorded
   - Methods for recording data

4. Methodology: Gives the overall methodology used to construct the Benchmark Suite in terms of portability, validity, and usability.

5. Using the Benchmarks: Explains how to use the benchmarks on a project. Emphasis is placed on making use of the suite command procedure environment to facilitate benchmarking.

# SECTION II

# BENCHMARK DEFINITIONS

## 1. BENCHMARK LEVELS

The CAMP Armonics Benchmark Suite supports benchmarking at three hierarchical levels:

- TLCSC benchmarks: complete operational subsystems;
- LLCSC benchmarks: sequentially driven calls to integrated CAMP parts;
- Unit benchmarks: benchmarks of individual parts. (This level is generally reserved for the benchmarks derived from CAMP polynomial parts .)

## 2. BENCHMARK CLASSES

The benchmark suite is functionally partitioned into three classes. The *compilation benchmarks* test the ability of an Ada compiler to process source code typical of armonics applications and reusable software. Benchmarks based on the CAMP Polynomials scientific function package are called the *polynomial benchmarks*. Finally, the benchmarks developed from CAMP higher-level armonics parts are referred to as *integrated execution benchmarks*. The following subsections define the three classes of benchmarks in greater detail.

### a. Compilation Benchmark Class

The compilation benchmarks test an Ada compiler's ability to process reusable software. The benchmarks concentrate on the complex syntax and semantics of several Ada armonics-oriented implementations using CAMP parts. These implementations are skeletal in that they do not actually implement an armonics subsystem but merely collect the necessary CAMP parts via generic instantiation. The instantiated parts *are* invoked in the benchmark code although the run-time effects of the invocations are not within the designed scope of testing. The compilation benchmarks are valid tests of a compiler only up to (and including) the linking phase.

### b. Polynomial Benchmark Class

The Benchmark Suite includes benchmarks based on the CAMP Polynomial parts (part number P688). These parts cover a range of basic mathematical functions, and provide a variety of techniques for obtaining results. For each benchmark, the benchmark drivers obtain both execution time data and function argument-result pairs. In addition, compilation and linkage editing of the polynomial benchmarks afford an opportunity to collect object code size data on all of the functions of the Polynomials package.

A software tool provided with the Benchmark Suite performs accuracy analysis and generates reports for the polynomial benchmarks. This tool takes the output produced by the benchmarks and generates a document incorporating time-consumption data and function-result accuracy measurement. The following information is provided by the tool:

- "Truth values" for each function over that function's benchmarked domain;
- Absolute error in the result of each argument-result pair
- Relative error in the result of each pair
- Maximum relative error tracking over the argument domain
- Maximum absolute and relative error over the argument domain
- Root-mean-square relative error over the argument domain

### c. Integrated Execution Benchmark Class

The integrated execution benchmarks test aggregations of CAMP armonics parts. These benchmarks concentrate on three of the major operational functions supported by the CAMP parts:

- Waypoint steering
- Navigation
- Kalman filter

In the waypoint steering and navigation cases above, data is gathered on CAMP parts in the context of an armonics application. This method has the virtue of testing the parts in the kinds of programs in which they will actually be applied. The benchmark based on the CAMP Kalman filter parts provides data on these parts as they operate in a unit testing environment. This method permits the full inclusion of all subprograms in the CAMP Kalman filter subsystem TLCSCs.

Output data from the integrated execution benchmark drivers consists of timing and result data on the benchmark subprograms. The timing data characterizes the execution time required to make a single call to the benchmark subprogram. The result data from the subprogram may be compared with the standard data supplied by CAMP as part of the Benchmark Suite. This comparison allows the engineer performing the benchmarks to spot errors and inaccuracies in run-time data processing on his system.

### d. Summary

Table 1 summarizes the benchmarks in the CAMP Armonics Benchmark Suite. For each benchmark, the table provides the following information:

- Benchmark name
- Benchmark number: a unique number for each set of benchmarks, corresponding to Section III of this document. This number gives the subsection and the paragraph of Section III where the benchmarks are described. In the case of the polynomial benchmarks, only the subsection number is applicable. The paragraph number tabulated for the polynomial benchmarks is only for serialization.
- Level: TLCSC (T), LLCSC (L), or Unit (U) as defined above
- Class: Compilation (C), Polynomial (P), or Integrated Execution (I) as defined above
- Objective: the objective of the benchmark
- Description: a description of the TLCSCs used in the benchmark (for the polynomial benchmarks, the description lists the polynomial expansion algorithm tested)
- Data to be recorded: summary of data values generated by running the benchmark and recorded in Appendix A of this report

## TABLE 1. CAMP ARMONICS BENCHMARK SUMMARY

(1 OF 2)

| Benchmark Name | No. | Lev. | Cls. | Objective | Description | Data to Record |
|---|---|---|---|---|---|---|
| Compilation 1 | 2.1 | L | C | Test compilability of parts needed in North Pointing Navigation. | Packages compiled: N_P_Nav_Parts, Polynomial_Parts, General_Purpose_Math, Coord_Vector_Matrix_Alg, Standard_Trig, Basic_Data_Types, Conversion_Factors, WGS72 (Metric), WGS72 (Unitless), Universal_Constants | Object code size. Successful compile. Compilation time. |
| Compilation 2 | 2.2 | L | C | Test compilability of parts needed in Waypoint Steering. | Packages compiled: Waypoint_Steering, Geometric_Operations, Coord_Vector_Matrix_Alg, Polynomial_Parts, General_Purpose_Math, Standard_Trig, Basic_Data_Types, Conversion_Factors, WGS72 (Metric), Universal_Constants | Object code size. Successful compile. Compilation time. |
| Compilation 3 | 2.3 | L | C | Test compilability of parts needed in Kalman Filter. | Packages compiled: Kalm_Filter_Compt_H_Parts, Kalm_Filter_Common_Parts, Polynomial_Parts, General_Purpose_Math, Kalman_Data_Types, General_Vector_Matrix_Alg | Object code size. Successful compile. Compilation time. |
| Integrated Execution 1 | 3.1 | T | I | Test execution efficiency of a guidance computation implementation. | Packages tested: Waypoint_Steering, Signal_Processing | Execution time. Code size. Result data. |
| Integrated Execution 2 | 3.2 | T | I | Test execution efficiency of a navigation operations implementation. | Packages tested: Comm_Navigation_Parts, Direction_Cosine_Matrix General_Purpose_Math, General_Vector_Matrix_Alg, Wander_Az_Nav_Parts | Execution time. Code size. Result data. |
| Integrated Execution 3 | 3.3 | T | I | Test execution efficiency of a Kalman Filter implementation. | Packages tested: Abstract_Data_Structs, Kalm_Filter_Common_Parts, Kalm_Filter_Compt_H_Parts, Kalm_Filter_Compx_H_Parts, | Execution time. Code size. Result data. |
| Sine Execution | 4.1 | U | P | Test execution efficiency and result precision of sine function. | Methods tested are: Taylor Series, Modified Taylor Series, Hastings Algorithm, Chebyshev Polynomial, System Functions | Execution time. Code size. Result Data |
| Cosine Execution | 4.2 | U | P | Test execution efficiency and result precision of cosine function. | Methods tested are: Taylor Series, Modified Taylor Series, Hastings Algorithm, Hart Algorithm, System Functions | Execution time. Code size. Result Data |

TABLE 1. CAMP ARMONICS BENCHMARK SUMMARY (CONCLUDED)

| Benchmark Name | No. | Lev. | Cls. | Objective | Description | Data to Record |
|---|---|---|---|---|---|---|
| Tangent Execution | 4.3 | U | P | Test execution efficiency and result precision of tangent function. | Methods tested are: Taylor Series, Modified Taylor Series, Hastings Algorithm, System Functions | Execution time. Code size. Result Data |
| Arcsine Execution | 4.4 | U | P | Test execution efficiency and result precision of arcsine function. | Methods tested are: Taylor Series, Fike Semicircle, System Functions | Execution time. Code size. Result Data |
| Arccosine Execution | 4.5 | U | P | Test execution efficiency and result precision of arccosine function. | Methods tested are: Taylor Series, Fike Semicircle, System Functions | Execution time. Code size. Result Data |
| Arctangent Execution | 4.6 | U | P | Test execution efficiency and result precision of arctangent function. | Methods tested are: Taylor Series, Continued Fraction, Hastings Algorithm, System Functions | Execution time. Code size. Result Data |
| Square Root Execution | 4.7 | U | P | Test execution efficiency and result precision of square root function. | Methods tested are: Newton-Raphson Modified Newton-Raphson | Execution time. Code size. Result Data |
| Log 10 Execution | 4.8 | U | P | Test execution efficiency and result precision of log 10 function. | Methods tested are: Taylor Series, Cody-Waite, System Functions | Execution time. Code size. Result Data |
| Log N Execution | 4.9 | U | P | Test execution efficiency and result precision of log n function. | Methods tested are: Taylor Series, Cody-Waite, System Functions | Execution time. Code size. Result Data |
| Natural Log Execution | 4.10 | U | P | Test execution efficiency and result precision of natural log function. | Methods tested are: Taylor Series, Cody-Waite | Execution time. Code size. Result Data |

# SECTION III

# PURPOSE AND DESIGN

## 1. GENERAL REQUIREMENTS

The CAMP Armonics Benchmark Suite meets the following general requirements:

- Utilizes CAMP parts in structures which simulate their actual use in typical user applications
- Utilizes test data modeled on typical user application data
- Helps assess Ada compilation capabilities, object code size, execution time, and output results
- Permits comparison between a variety of host/target combinations using different Ada compiler/run-time systems
- Allows modification to meet specific needs of future users
- Exhibits high portability
- Is highly automated

### a. Identifying Ada Compiler Inadequacies

One problem faced during the development of the CAMP parts was the inability of some Ada compilers to process complex generic units. This is important because Ada generic units play a pivotal role not only in the future development of reusable software, but also in the application of that software. In order to identify Ada compiler inadequacies in the area of reusable software the CAMP benchmarks provide Ada source code benchmarks which heavily utilize Ada generic units.

The compilation benchmarks of the Armonics Benchmark suite go beyond the limited scope of testing in the official Ada Compiler Validation Capability (ACVC) tests. While the ACVC tests demonstrate conformance to the Ada language specification, the effect of *combining* language features in complex ways is not sufficiently addressed. The CAMP compilation benchmarks attempt to bridge the gap between the objectives of the ACVC tests and the necessities of complex software applications. It is believed at this point that very few ACVC-validated Ada compilers will, in fact, correctly handle the CAMP compilation benchmarks.

### b. Testing Calculation Accuracies

The CAMP parts, including those selected as benchmarks, consist of portable Ada source code. However, certain aspects of the run-time performance of the parts may still vary from system to system. The accuracies of numeric computations, for instance, are guaranteed by the Ada language definition to meet the minimum requirements specified in the software, but, this does not mean that different compiler implementations of Ada will handle numeric computations in the same way. A compiler is free both to provide *more* accuracy than is requested by application software, and to support *less* accuracy based on the limitations of the target machine. For this reason, the results of calculations performed by portable software may not themselves be portable. Differences in numeric accuracies and range limits in Ada systems introduce the possibility of unanticipated error in extensive calculations. This factor must be considered by potential users of the CAMP parts as it would have to be by users of any software (or hardware) product.

The two classes of execution benchmarks (polynomial and integrated execution) in the Armonics Benchmark Suite address the issue of varying computational accuracies in different Ada systems. They provide a standard means of generating data from the kinds of complex calculations involved in armonics applications.

### c. Testing Time and Space Performance

An important performance factor in real-time embedded (RTE) environments is space and time efficiency: Software must be kept small because hardware must be kept small in RTE systems; software must also operate efficiently because of the throughput requirements of real-time processing. The execution benchmarks of the Benchmark Suite support execution-time testing of CAMP parts as they operate on various Ada compiler/target machine systems. Selected CAMP parts make up the benchmarks which cover operations common to many armonics applications.

The size of the object code generated from the benchmarks reflects the qualities of the compiler, the CAMP parts, and, to a lesser extent, the instruction set architecture of the application target machine. Although RTE systems are being built with more and more memory, hardware capacity and its associated costs are still the major limiting factor in increasing the computational power of embedded applications. The execution benchmarks of the Benchmark Suite should facilitate the evaluation of Ada compiler/linker systems based on object code size. Linker map data, obtained by compiling and linking the benchmarks, can be utilized in judging an Ada system's appropriateness to an embedded application in the light of hardware capacity constraints.

## 2. COMPILATION BENCHMARKS

The purpose of the compilation benchmarks is to determine the compilability and linkability of a large selection of CAMP parts integrated into typical armonics application groupings. Results from compiling this series of benchmarks reflect on the ability of Ada compilers to correctly process CAMP parts. Since these parts are both reusable and armonics application-oriented, the validity of the benchmarks extends strongly to these two areas.

### a. Compilation Group 1

CAMP parts utilized as benchmarks in Compilation Group 1 represent those which might be needed in a north-pointing navigation implementation. The structure, components, and operating procedure of this compilation benchmark follow.

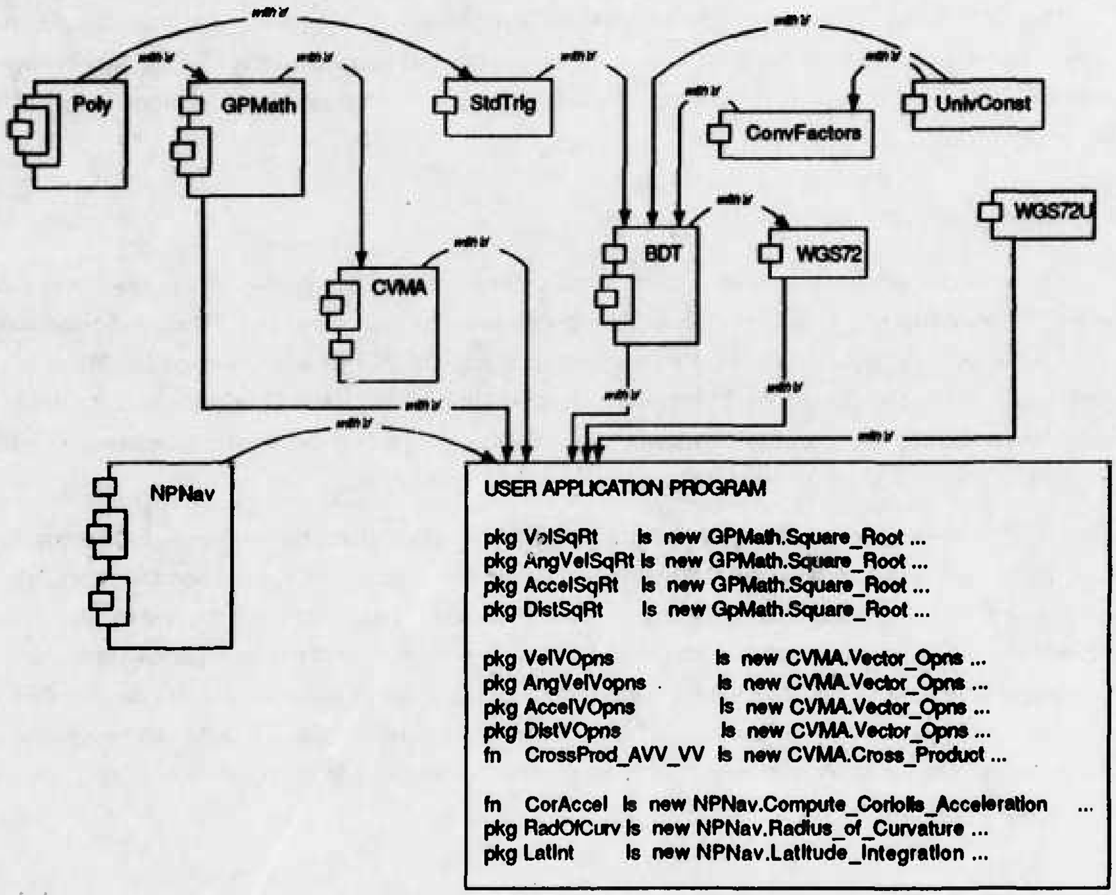



**Figure 1.** Compilation 1 Structure

- Compilation structure: Figure 1 depicts the compilation structure. An Ada main procedure is compiled in the context of several CAMP packages. The order of compilation for the packages corresponds to the partial ordering induced by the context clauses (*with* statements) of the packages

and driver procedure. A command file in the tool set supplied with the benchmark suite gives a correct compilation order and compiles the compilation benchmarks automatically on VAX/VMS.

- Benchmark driver design:

  1. Import North_Pointing_Navigation_Parts (CAMP part number P001), General_Purpose_Math (P687), Coordinate_Vector_Matrix_Algebra (P681), Basic_Data_Types (P621), WGS72_Ellipsoid_Metric_Data (P611), WGS72_Ellipsoid_Unitless_Data (P613), and SYSTEM.

  2. Begin main procedure definition.

  3. Declare types and subtypes necessary for benchmark.

  4. Instantiate generic units from imported packages.

  5. Declare objects necessary for benchmark.

  6. Invoke instantiated and derived subprograms (executable part of driver).

  7. End main procedure definition.

- Data to be recorded:

  1. Successful compilation;

  2. Successful link;

  3. Object code size (size of load module produced, if any);

  4. CPU time consumed by the compiler.

- Methods for recording data: The source files for this compilation benchmark are compiled in one group with the source files for the others. Error-free compilation is indicated by the compiler through listings or by some other mechanism. CPU time consumption is noted when it is reported by the compiler. The driver program is then linked and the size of the executable image recorded.

**b. Compilation Group 2**

CAMP parts utilized as benchmarks in Compilation Group 2 represent those which might be needed in the waypoint steering of a missile application. The structure, components, and operating procedure of this compilation benchmark follow.

- Compilation structure: Figure 2 depicts the compilation structure. The structure is similar to that of Compilation Group 1.
- Benchmark driver design:
    1. Import Waypoint_Steering (CAMP part number P661), General_Purpose_Math (P687), Coordinate_Vector_Matrix_Algebra (P681), Basic_Data_Types (P621), WGS72_Ellipsoid_Metric_Data (P611).
    2. Begin main procedure definition.
    3. Declare types and subtypes necessary for benchmark.
    4. Instantiate generic units from imported packages.
    5. Declare objects necessary for benchmark.
    6. Invoke instantiated and derived subprograms.
    7. End main procedure definition.
- Data to be recorded: As in compilation group 1
- Methods for recording data: As in compilation group 1

**c. Compilation Group 3**

CAMP parts utilized as benchmarks in Compilation Group 3 represent those which might be needed in a Kalman filter of a missile application. The structure, components, and operating procedure of this compilation benchmark follow.

- Compilation structure: Figure 3 depicts the compilation structure. The structure is similar to that of the other two compilation groups.
- Benchmark driver design:
    1. Import Kalman_Filter_Complicated_H (CAMP part number P653) and Kalman_Filter_Data_Types (P622).
    2. Begin main procedure definition.
    3. Declare types and subtypes necessary for benchmark.
    4. Instantiate generic units from imported packages.

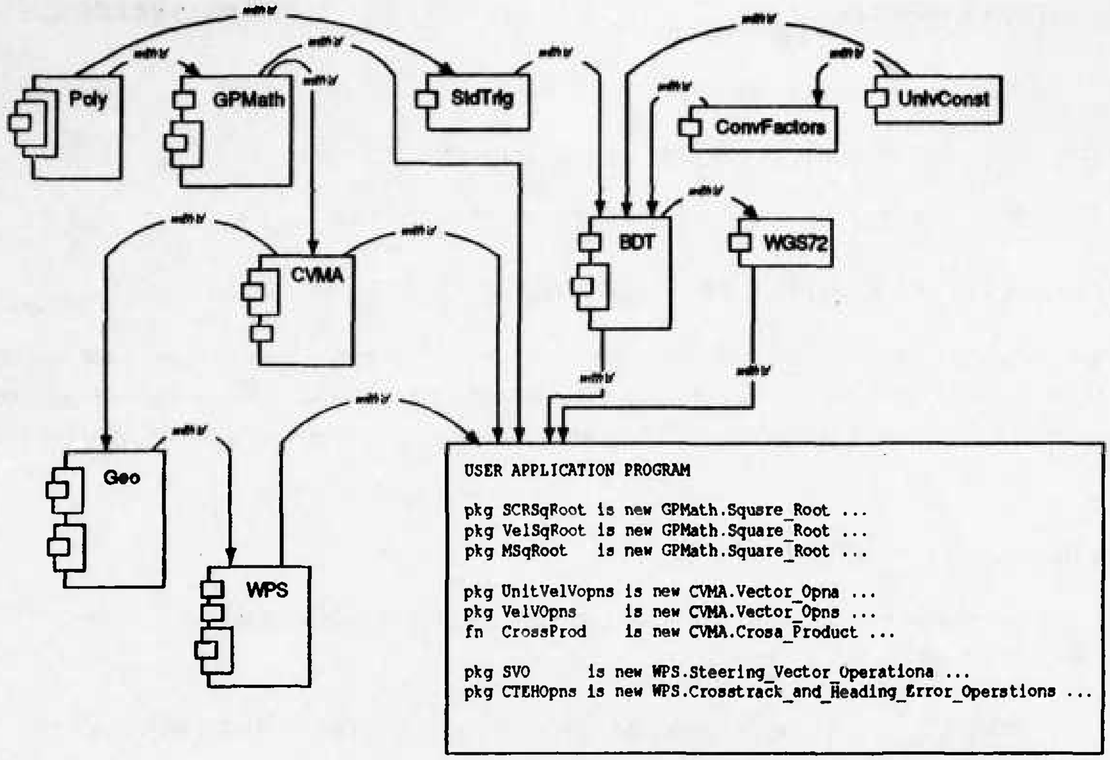



**Figure 2. Compilation 2 Structure**

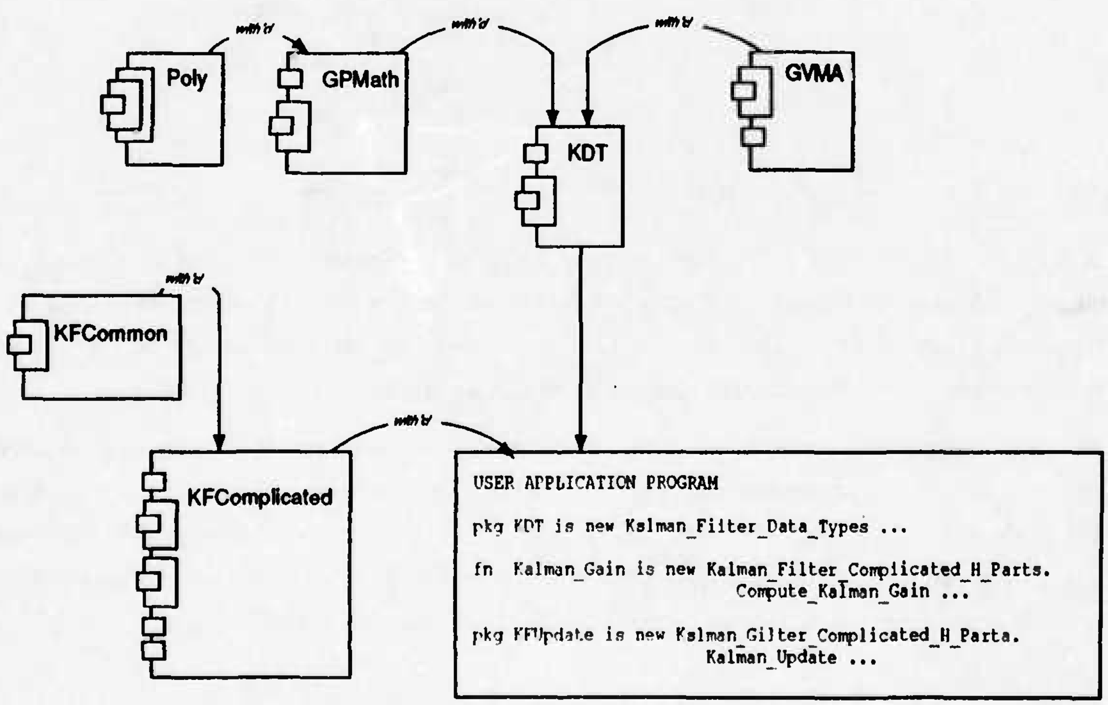



**Figure 3. Compilation 3 Structure**

5. Invoke instantiated subprograms.

6. End main procedure definition.

- Data to be recorded: As in the other two compilation groups

- Methods for recording data: As in the other two compilation groups

## 3. INTEGRATED EXECUTION BENCHMARKS

This section describes execution benchmarks based on CAMP parts, both integrated for use in a typical missile application and in a unit-testing environment. The purpose of the integrated execution benchmarks is to generate data on these CAMP parts and to afford an opportunity for determining code sizes.

### a. Integrated Execution 1

In this section a benchmark based on a guidance computer implementation is described. Table 2 lists the CAMP parts used in this benchmark.

TABLE 2. CAMP PART BENCHMARKS OF INTEGRATED EXECUTION 1

| TLCSC NAME | PART NO. | LLCSC NAMES |
|---|---|---|
| Waypoint Steering | P661 | Compute Turn Angle and Direction<br>Compute Turning and Nonturning Distances<br>Distance to Current Waypoint<br>Steering Vector Operations with Arcsine<br>Turn Test Operations<br>Cross Track and Heading Error Operations |
| Signal Processing Parts | P686 | Absolute Limiter<br>Upper Lower Limiter |

- Benchmark Driver Design: This benchmark is based on the guidance computer of a missile application. The driver consists of several task bodies declared in the declaration section of a main procedure. These tasks are activated after the elaboration of the driver declaration section. A null executable part of the driver runs to completion and awaits the termination of the tasks.

  The tasks call the benchmark subprograms in the course of execution. A counter keeps track of calls to a central message management task. When the counter value reaches a certain level, the task is aborted and becomes abnormal. As the other tasks attempt to rendezvous with the aborted task, they are forced to select a "terminate" entry. Then, these tasks also become abnormal. When the child tasks of the driver have all become abnormal, the driver terminates execution.

- Data to be recorded:

  - Execution time

  - Code sizes

- Result data

- Methods for recording data: Execution time is obtained directly from the benchmark driver. The code sizes of the various CAMP parts may be taken from linker map files. Result data is also generated directly by the benchmark.

- Benchmark inputs: Before execution, the benchmark driver requests data about the system: the compiler used, the compiler host, and the compiler target. Then iteration values are requested to tell the driver how many times to execute a benchmark subprogram. The benchmarks themselves are supplied with hard-coded input data by the driver software. These inputs are coded as variables to preserve the functionality of the benchmarks, which would not normally process static data.

- Benchmark correct outputs: A file containing standard output is supplied with the benchmark suite. It should be used for comparison with the actual benchmark output.

### b. Integrated Execution 2

In this section a benchmark based on a navigation computer implementation is described. Table 3 lists the CAMP parts used as benchmarks.

**TABLE 3. CAMP PART BENCHMARKS OF INTEGRATED EXECUTION 2**

| TLCSC NAME | PART NO. | LLCSC NAMES |
|---|---|---|
| Common Navigation Parts | P001 | Update Velocity<br>Compute Ground Velocity<br>Compute Gravitational Acceleration Sin Lat In |
| Wander Azimuth Navigation Parts | P002 | Radius of Curvature<br>Compute East Velocity<br>Compute North Velocity<br>Compute Latitude using 2-Value Arctan<br>Compute Longitude using 2-Value Arctan<br>Compute Wander Azimuth Angle<br>Earth Rotation Rate<br>Earth Relative Navigation Rotation Rates<br>Compute Coriolis Acceleration<br>Total Platform Rotation Rate |
| Direction Cosine Matrix | P644 | CNE Operations |
| General Vector Matrix Algebra | P682 | Matrix Matrix Multiply Restricted |
| General Purpose Math Parts | P687 | Accumulator |

- Benchmark Driver Design: This set of three benchmark drivers is based on the navigation operations of a missile application. Each driver uses the same basic Ada linkage closure of units, substituting dummy code as appropriate. The first phase of the benchmarking run is done by the driver, "Execute_Navigator_Test," which calls most of the benchmark subprograms. The remaining benchmark subprograms are called by two drivers embedded in the executable part of the Navigation Operations package.

- Data to be recorded:

1. Execution time

2. Code size

3. Result data

- Methods for recording data: As in Integrated Execution 1
- Benchmark inputs: As in Integrated Execution 1
- Benchmark correct outputs: As in Integrated Execution 1

### c. Integrated Execution 3

In this subsection a benchmark based on the CAMP Kalman filter unit tests is described. Table 4 lists the CAMP parts used as benchmarks.

**TABLE 4. CAMP PART BENCHMARKS OF INTEGRATED EXECUTION 3**

| TLCSC NAME | PART NO. | LLCSC NAMES |
|---|---|---|
| Kalman Filter Common Parts | P651 | Error Covariance Matrix Manager<br>State Transition and Process Noise Matrices Manager<br>State Transition Matrix Manager |
| Kalman Filter Compact H Parts | P652 | Compute Kalman Gains<br>Update Error Covariance Matrix<br>Update State Vector<br>Sequentially Update Covariance Matrix And State Vector<br>Kalman Update<br>Update Error Covariance Matrix General Form |
| Kalman Filter Complicated H Parts | P653 | Compute Kalman Gain<br>Update Error Covariance Matrix<br>Update State Vector<br>Sequentially Update Covariance Matrix And State Vector<br>Kalman Update<br>Update Error Covariance Matrix General Form |

- Benchmark driver design: The three drivers of this benchmark are based on the unit tests of the CAMP Kalman filter parts (P651, P652, and P653). Three main procedures import the three Kalman TLCSCs and call the benchmark subprograms within them.
- Data to be recorded:

  - Execution time
  - Code size
  - Result data

- Methods for recording data: As in the other two integrated execution benchmarks
- Benchmark inputs: As in the other two integrated execution benchmarks
- Benchmark correct outputs: As in the other two integrated execution benchmarks

## 4. POLYNOMIAL BENCHMARKS

The purpose of the polynomial benchmarks is to generate run-time data on the "slide rule" functions of the CAMP Polynomials package and to provide an opportunity for collecting object code size data. The run-time data on the benchmarks is produced by benchmark drivers and includes information both on the time-consumption of the benchmarks and the numeric output they produce.

Table 5 presents a summary of the execution benchmarks which have been created from the CAMP Polynomials parts. Entries marked "X" indicate a function and a numerical algorithm. For each mathematical function of the CAMP Polynomials package, all of the available algorithm implementations are used as benchmarks. The floating point types of the arguments and results are varied according to the number of terms in each algorithm's polynomial expansion. For example, an algorithm for a 5-term polynomial expansion may be instantiated to use 6 floating-point digits while an algorithm for a 7-term expansion is instantiated to use 9 digits.

**TABLE 5. CAMP POLYNOMIAL PARTS EXECUTION BENCHMARKS**

| Function | Taylor Series | Modified Taylor Series | Hastings | Chebyshev | System Functions | Hart | Fike | Continued Fraction | Newton-Raphson | Modified Newton-Raphson | Cody-Waite |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Sine | X | X | X | X | X | | | | | | |
| Cosine | X | X | X | | X | X | | | | | |
| Tangent | X | X | X | | X | | | X | | | |
| Arcsine | X | | | | X | | X | | | | |
| Arccosine | X | | | | X | | X | | | | |
| Arctangent | X | | X | | X | | | X | | | |
| Square root | | | | | | | | | X | X | |
| Log 10 | | | | | X | | | | | | X |
| Log 2 | | | | | X | | | | | | X |
| Nat. Log | | | | | | | | | | | X |

Tables 6 through 12 present details of the polynomial function benchmarking. An "X" entry in a table indicates an algorithm for computing a function and the number of terms of that algorithm to be applied in the computation. Detail tables are not included for the various log functions shown in Table 5 since the log function testing is confined to the Polynomials Cody-Waite LLCSC. Term counts are not applicable to the parts of this LLCSC.

- Benchmark driver design (for all polynomial benchmarks):
  1. Import the CAMP Polynomials package (P688), Benchmarking_Tools package, and the Polynomial_Benchmark package.
  2. Define a floating point type of some precision.
  3. Instantiate a Polynomials package LLCSC for the defined type.
  4. Instantiate the Polynomial_Benchmark package for the defined type.

## TABLE 6. DETAIL OF SINE PERFORMANCE BENCHMARKS

| Number of Terms | Taylor Series | Modified Taylor Series | Hastings Algorithm | Chebyshev Polynomial | System Functions |
|---|---|---|---|---|---|
| 4 | X | X | X | | |
| 5 | X | X | X | X | |
| 6 | X | X | | | |
| 7 | X | X | | | |
| 8 | X | X | | | |
| VAX | | | | | X |

5. Instantiate the Benchmark procedure (procedure named Benchmark) from the Polynomial_ Benchmark package. Pass in a function subprogram as a generic actual parameter. This is the subprogram to be benchmarked. Pass in an identity function from the Benchmarking_ Tools package as another generic actual parameter. This subprogram helps to compensate for time costs associated with the design of the benchmark driver software. A new Benchmark procedure instantiation is required for each subprogram benchmark from the Polynomials package.

6. Request the system information. This includes the name of the compiler used to compile the benchmark and the names of the host and target machines of the compiler. This data is incorporated into the benchmark driver output to note the environment in which the benchmark is being carried out. See "Benchmark Correct Outputs" below.

7. Request the number of iterations to use for each benchmark. Separate numbers are requested: one for the number of iterations to use when timing the benchmark, the other for the iterations to use when collecting data from the benchmark.

8. Call the instantiated Benchmark procedures. These procedures time the benchmark subprogram over a selected domain. They also provide input and output data echoing for the benchmark subprogram over the argument domain.

9. End of benchmark definition.

- Benchmark inputs: System information and iteration values are supplied at run-time via the console.

- Benchmark correct outputs: The benchmarks produce time-consumption data as well as: echoed system information (noted above), an Ada enumeration literal for the function being benchmarked (e.g. SINE_R for radian sine), and ordered pairs of benchmark subprogram input and output. Accuracy of the subprogram output is determined by an analysis program supplied with the Benchmark Suite. This program uses the VAX Ada Math library (MATH_LIB) to obtain truth values. Absolute error in a benchmark subprogram is calculated as the difference between the result of that subprogram and the truth value result for a given argument.[2]

- Data to be recorded:

  1. Execution time for one call to each Ada subprogram benchmark

  2. Code size

  3. Arguments and benchmark function results for those arguments

  4. System information collected at the beginning of the run

- Methods for recording data: Time-consumption data is recorded and reported automatically by the benchmark drivers. Input data, output data, system information echoing, and an enumeration literal representing the kind of function benchmarked are also reported automatically. Analyzed output is obtained by passing the benchmark driver output through the analysis program Analyze. Code size information is retrieved from linker maps.

**TABLE 7. DETAIL OF COSINE PERFORMANCE BENCHMARKS**

| Number of Terms | Taylor Series | Modified Taylor Series | Hastings Algorithm | Hart Algorithm | System Functions |
|---|---|---|---|---|---|
| 4 | X | X | X | | |
| 5 | X | X | X | X | |
| 6 | X | X | | | |
| 7 | X | X | | | |
| 8 | X | X | | | |
| VAX | | | | | X |

[2]Note: a small amount of error is induced by conversion to and from text representations of floating-point numbers.

**TABLE 8. DETAIL OF TANGENT PERFORMANCE BENCHMARKS**

| Number of Terms | Taylor Series | Modified Taylor Series | Hastings Algorithm | Continued Fraction | System Functions |
|---|---|---|---|---|---|
| 4 | | X | X | X | |
| 5 | | X | X | X | |
| 6 | | X | | X | |
| 7 | | X | | X | |
| 8 | X | X | | X | |
| 9 | | | | X | |
| 10 | | | | X | |
| 11 | | | | X | |
| VAX | | | | | X |

**TABLE 9. DETAIL OF ARCSINE PERFORMANCE BENCHMARKS**

| Number of Terms | Taylor Series | Fike Semicircle | System Functions |
|---|---|---|---|
| 5 | X | | |
| 6 | X | X | |
| 7 | X | | |
| 8 | X | | |
| VAX | | | X |

**TABLE 10. DETAIL OF ARCCOSINE PERFORMANCE BENCHMARKS**

| Number of Terms | Taylor Series | Fike Semicircle | System Functions |
|---|---|---|---|
| 5 | X | | |
| 6 | X | X | |
| 7 | X | | |
| 8 | X | | |
| VAX | | | X |

## TABLE 11. DETAIL OF ARCTANGENT PERFORMANCE BENCHMARKS

| Number of Terms | Taylor Series | Alternate Taylor Series | Hastings Algorithm | Modified Hastings Algorithm | Continued Fraction | System Functions |
|---|---|---|---|---|---|---|
| 4 | X | X | | | X | |
| 5 | X | X | | | X | |
| 6 | X | X | X | X | X | |
| 7 | X | X | X | X | X | |
| 8 | X | X | X | X | X | |
| 9 | | | | | X | |
| 10 | | | | | X | |
| 11 | | | | | X | |
| VAX | | | | | | X |

## TABLE 12. DETAIL OF SQUARE ROOT PERFORMANCE BENCHMARKING

| Number of Terms | Newton-Raphson | Modified Newton-Raphson | System Functions |
|---|---|---|---|
| 4 | | | |
| 5 | | | |
| 6 | X | X | |
| 7 | | | |
| VAX | | | X |

# SECTION IV

# METHODOLOGY

The following paragraphs explain methods used in constructing the Armonics Benchmark Suite. These sections discuss the overall design aspects of the suite as applied to the problems of portability, validity, and automation of data collection.

## 1. PORTABILITY

Like the CAMP parts in general, the Benchmark Suite is highly portable, extending its usability and repeatability to many different Ada systems. The CAMP parts selected as benchmarks use only Mil-Std-1815A Ada code, as do the drivers which automate much of the benchmarking. Whenever optional Ada features are applied (e.g., pragma PAGE), their effects are irrelevant and they may be freely ignored by Ada compilers.

Input to and output from the benchmarks is limited to the use of the console, obviating file I/O implementation in the target system. While a filing system is desirable in order to retain output, the console I/O approach possesses greater versatility since many embedded computers (and hosted debugger/simulators for the same) may not fully support file I/O. In such cases, the use of file I/O could make the benchmarks difficult to transport to the kinds of architectures for which they are intended. Moreover, the use of console I/O does little to impede the retention of benchmark data on a filing system. The Ada language and most operating systems supply trivial mechanisms for redirecting console output to files.

The tool set which accompanies the benchmark suite is system-dependent and, as previously noted, consists of VAX DCL command procedures and some non-portable Ada. Designed to automate the compilation and execution of the benchmarks, this tool set supports two possible uses: For VAX/VMS users, the tool set substantially automates benchmarking; for users of other systems, the tools are well documented to permit a knowledgeable user to modify them or use them as a guide for performing the benchmarks on his own system. A more detailed treatment of the tools is presented in Section V.

In order to automate the timing of benchmark executions in a portable way, the benchmark drivers use facilities from the Ada CALENDAR package. Although differences in the implementation of this package may exist between systems, these differences are minor enough that their effects can be minimized. The design of the benchmark drivers attempts to take advantage of similarities in Ada systems supporting the CALENDAR package, while accounting for the differences that exist.

For example, the duration of a basic clock cycle (Ada SYSTEM.TICK) may vary from system to system and may be quite large with respect to the benchmark execution times. This requires a benchmark driver to execute its benchmark many times in order to arrive at a reasonable one-call execution-time estimate. By examining the Ada constant SYSTEM.TICK, the drivers are able to calculate the number of benchmark executions necessary to arrive at a set timing accuracy. Conversely, given the number of executions used in benchmarking, the drivers calculate an estimated accuracy on the time-consumption data obtained from those executions.

## 2. COMPILATION BENCHMARK METHODS

The compilation benchmarks are valid tests of a compiler but do not apply to code generation. They are intended to force an Ada compiler/linker system to fail when it contains errors in semantic analysis, in library management, or in linkage editing.

To pass the compilation benchmark test, a compiler must process the associated Ada source code without signaling any errors or ending abnormally. Limited warnings are allowed since the Ada language allows a compiler some flexibility. For example, a compiler can warn that it has made an optimization or ignored an optional pragma. Warnings about program semantics, however, should not be generated, nor should the compiler or linker encounter fatal errors in library management or load module generation.

The compilation benchmarks are performed by a DCL command procedure. This procedure must be supplied with a compiler invocation command and a linker invocation command. It then proceeds to apply these commands to the necessary Ada source files in a correct order. The procedure can be altered or used as a guide when benchmarking on systems other than VAX/VMS.

The compilation benchmarks were validated by successfully compiling, linking, and running their source code on a highly reliable Ada compiler/linker system. The system on which the validation was performed is ACVC validated and produced no error messages or warnings in the course of compiling, linking, and running the compilation benchmark source code.

## 3. EXECUTION BENCHMARK METHODS

### a. Collecting Valid Timing Data

Drivers of the execution benchmarks collect time-consumption data through the use of the Ada CALENDAR package. As noted above, the Ada constant SYSTEM.TICK varies between systems and is usually quite large. Because of this the benchmarks are called repeatedly for the sake of timing accuracy. The number of repetitions necessary to achieve microsecond accuracy is computed relative to SYSTEM.TICK and reported by the benchmark drivers at run-time. This enables a user of the Benchmark Suite to decide on the number of repetitions to actually use in benchmarking.

The computed number of repetitions is not used automatically since the resulting processing time of the benchmark drivers might, in some cases, become prohibitively long. Large numbers of repetitions on slow systems may consume a substantial amount of CPU time. Reducing the number of repetitions proportionally reduces both the driver CPU-time expense and, unfortunately, the accuracy of

the collected benchmark timings. The engineer who runs the benchmarks must, therefore, make a trade-off with respect to timing accuracy and the use (or overuse) of computational resources.

In order to ensure valid timings of the benchmarks, a number of precautions are built into the system. Code optimizations which might affect the integrity of the time-consumption data are selectively defeated while other optimizations remain untouched. The methods used are similar to those used in ACVC tests to prevent the compile time removal of code which is being tested. These methods entail the use of identity functions and tautological BOOLEAN functions to deprive the compiler of optimization opportunities. Here, the goal of optimization suppression is essentially to "fool" the compiler by reducing its available control-flow information at compile time.

For example, consider Figure 4. The identity function used in the first part of this Ada fragment prevents a compiler from propagating the constant "5" into the timing loop in place of the variable Argument. If this propagation were allowed to occur, the measured time for the subprogram call could be reduced. The reduction, however would be due to the static nature of the argument, a circumstance which would not often occur if the subprogram were used in an application. This method of optimization suppression is used in the integrated execution benchmarks where constants are often supplied as arguments.

```
        ...

Argument := Identity(5);  -- instead of "Argument := 5;"
Start_Timer;
for Index in Some_Range loop
   Result := Benchmark_Function (Argument);
end loop;
Stop_Timer;

        ...
```

Figure 4. Identity Function Defeats Constant Propagation

In a second example, Figure 5 shows the use of a tautological BOOLEAN function to prevent the removal of a "dead" assignment. The function, Snow_Is_White, always returns the value TRUE, although this is not known at compile time by the compiler (the body of the function is separate). Since the flow of control is not known, the compiler cannot remove the assignment to the variable Gross_Time. If this optimization were allowed, the compiler could move the evaluation of the Get_Elapsed_Time_Since_Start function into the expression assigned to the variable Next_Time_Used. While such a move would not alter the logical meaning of the program, a small effect on the time data would result. This optimization suppression is used in the polynomial benchmarks.

It should be noted that these techniques do not have the negative effect of inhibiting desired optimizations. An Ada compiler is free to optimize all unprotected source code, including the code bodies of the benchmarks themselves. It should also be noted, however, that these techniques are not fool-proof. Conceivably, a smart enough compiler/linker could outwit the optimization suppressions described here.

```
        ...

Start_Timer;
for Index in Some_Range loop
   Argument := Identity (Argument);    -- loop determines overhead
end loop;
if Snow_Is_White then                             -- balances "if" below.
   Overhead_Time := Get_Elapsed_Time_Since_Start;
end if;

Start_Timer;
for Index in Some_Range loop
   Argument := Identity (Argument);
   Result   := Benchmark_Function (Argument);
end loop;
if Snow_Is_White then                             -- function always TRUE
   Gross_Time := Get_Elapsed_Time_Since_Start;   -- removal prevented
end if;
Net_Time_Used := Gross_Time - Overhead_Time;

        ...
```

**Figure 5.** Tautological Function Prevents Assignment Removal

Figure 5 also illustrates the collection of time-overhead to calibrate benchmark timings. Time overheads are calculated at run-time and are used to offset the effects of the timing method and benchmark code idiosyncracies. In the case of the polynomial benchmarks, the overheads are often negligible, since none of these benchmarks require initialization.

On the other hand, the execution time overheads of the integrated execution benchmarks are usually appreciable due to the parameter requirements of the benchmark subprograms. Many of the higher-order CAMP parts used as integrated execution benchmarks have side effects and in-out parameters. Each execution of such a benchmark, therefore, has a cumulative effect which may produce an exception after many iterations. In order to counteract this effect, many of the integrated execution benchmarks must be re-initialized prior to each call, a process which adds very significantly to overhead. The resolution of this problem is transparent to the user and is accomplished by, as in the polynomial benchmarks, implementing automatic overhead correction in the benchmark drivers.

Despite all of the precautions taken to ensure the validity of the time-consumption data, inaccuracies may still occur. The benchmark drivers may overestimate benchmark execution times when asynchronous events take place in the midst of timing. For example, if the benchmark drivers are operated on a time-sharing operating system, they will compete with other processes. Since the CALENDAR package operates on wall-clock time rather than CPU time consumption, the benchmarks will appear to execute longer as their CPU time fraction is reduced.

Problems of this kind are beyond the control of the benchmark drivers. The effects of asynchronous events on the benchmark timings may be minimized, but inaccuracies should nevertheless be assumed. When asynchronous interference with the benchmarks is relatively uniform, the benchmark execution times will lengthen proportionally to their synchronous execution times. Benchmarks which, by themselves, take a relatively long time to run will, of course, show a relatively larger dilation in measured execution time. While this effect may be undesirable, it can usually be taken into account.

Moreover, timings which include asynchronous interference, typical of an operating environment, are quite valid. In such an environment, estimates based on the CPU time consumption alone would be unrealistically low. The true throughput of an application is a function of both the application execution speed and the typical amount of asynchronous interference with which the application must contend.

### b. Collecting Benchmark Output Data

In addition to timing data, the polynomial benchmarks provide data for use in determining the accuracy of Polynomials (CAMP package) function results. For each function benchmarked, both input and output are reported at equal intervals over a selected argument domain. This permits the result accuracies of the functions to be checked against appropriate truth values. For users with access to VAX Ada, accuracy analysis and report generation can be accomplished automatically using a tool provided with the Benchmark Suite. Other users may make use of this tool by modifying it as explained in section V. It should be noted, however, that the accuracy analysis tool is not required in order to run the benchmarks.

Armonics subsystem output data is also produced by the integrated execution benchmarks although automatic checking of this data is not supported. Most of the output from these benchmarks is produced in an ad hoc format which does not lend itself to automatic analysis. Nevertheless, the correctness of the data may be checked by manual comparison with standard output files supplied with the Benchmark Suite.

### c. Automation of the Execution Benchmarks

The compilation and implementation of the execution benchmarks is highly automated in the Armonics Benchmark Suite. Depending on the computer system used, most of the benchmarking, from installation to report generation, may be accomplished in one or two man-days. In addition, once an engineer has conformed the Benchmark Suite to run on a particular system, the work can be easily repeated as necessary.

Compilation of the source code of the execution benchmarks is explained in detail in the next section. The process involves the use of VAX/VMS command procedures as discussed above for the compilation benchmarks. Once again, these command procedures may be used directly on a VAX, modified on systems which support batch processing, or used as a guide on other systems.

The process of *running* the benchmarks is automated at two levels. First, the benchmarks themselves (i.e. the chosen CAMP parts) are automatically executed by the portable Ada drivers in which they

are embedded. Thus, the engineer with the task of benchmarking is not required to supply an Ada driver with which to execute the benchmarks. Second, at a higher level, the benchmark drivers are executed using VAX DCL command procedures, written for inclusion with the Benchmark Suite. This level of automation is, of course, subject to system dependencies.

# SECTION V

# USING THE BENCHMARKS

The following sections explain how to perform benchmarking using the CAMP Armonics Benchmark Suite. For the purposes of discussion, the VAX/VMS environment is assumed. Comments throughout suggest possible ways of adapting the Benchmark Suite to other environments.

Table 13 lists the DCL command procedure files which are supplied with the Benchmark Suite. On a VAX, these command procedures automate both the compilation and the execution of the benchmark drivers. On other systems the command procedures serve as a guide although they may be altered as necessary to conform to other batch-processing systems.

## 1. LOGICAL DIRECTORIES

A system of three directories is recommended for compiling and executing the benchmark code in a VAX/VMS environment. These directories are referred to within the Benchmark Suite command procedures by the following VMS logical names:

- Compilation_Directory: The directory on which all compilation takes place.
- Tools: The directory which contains the Benchmark Suite command procedures, and
- Source: The directory which contains all of the Ada source code supplied with the benchmarks.

On systems which do not support the concept of logical names, the command procedures may be altered to use the desired operating system names and batch job control style. Systems which do not support the concept of directories at all may store all of the files (over 360 in number) in a single location and alter the command procedures accordingly.

## 2. USING THE COMPILATION BENCHMARKS

The compilation benchmarks are simply files of Ada source code. Testing a compiler/linker system with the benchmarks involves compiling the Ada code in a correct order and then linking the three linkable main procedures. For VAX/VMS-hosted Ada compilers the process is automatic depending slightly on the command syntax used to invoke the subject Ada compiler and linker.

The file called VAX_Compilation_Run.Com gives an example of how to perform the compilation and linkage editing of the compilation benchmarks on VAX/VMS, using the VAX Ada compiler and (via ACS) the VMS linker. The procedure sets its process to run in the logical Compilation_Directory and then calls the command procedure Compilation_Benchmarks to perform the compilation and the linkage editing. On other systems, the Compilation_Benchmarks procedure gives a correct compilation order for the Ada source files and may be used as a guide or altered as necessary.

## TABLE 13. BENCHMARK SUITE COMMAND PROCEDURES

| COMMAND PROCEDURE | PURPOSE |
|---|---|
| ACT_COMPILATION_RUN | Calls Compilation_Benchmarks to compile/link the compilation benchmarks on the ACT compiler. |
| ANSI2DV & DV2ANSI | Rename files from ANSI to development names and reverse. |
| COMPILATION_BENCHMARKS | Compiles/links source code for the compilation benchmarks. |
| COMPILE_BENCHMARK_SUPPORT | Compiles support code for the execution benchmarks. |
| COMPILE_TOOLS | Compiles the clock function and I/O tools of the execution benchmarks. |
| INT_EXEC1_COM_LINK | Compiles/links Ada source code for integrated execution 1 |
| INT_EXEC2_COM_LINK | Compiles/links Ada source code for integrated execution 2 |
| INT_EXEC3_COM_LINK | Compiles/links Ada source code for integrated execution 3 |
| MODIFIED_POLY6_COM_LINK | Compiles/links the 6-digit precision polynomial benchmarks on the TLD compiler. |
| MODIFIED_POLY9_COM_LINK | Compiles/links the 9-digit precision polynomial benchmarks on the TLD compiler. |
| POLY6_COM_LINK | Compiles/links the 6-digit precision polynomial benchmarks. |
| POLY9_COM_LINK | Compiles/links the 9-digit precision polynomial benchmarks. |
| SYSTEM_COM_LINK | Compiles/links code to run the System polynomial benchmark. |
| TLD_BENCHMARKS_COM_LINK | Calls other procedures to compile/link the benchmarks on the TLD compiler. |
| TLD_COMPILATION_RUN | Calls Compilation_Benchmarks to compile/link the compilation benchmarks on the TLD compiler |
| VAX_ANALYZE_COM_LINK | Compiles/links the Analyze.Ada program. The program is VAX/VMS and VAX Ada dependent. |
| VAX_ANALYZE_POLY | Uses Analyze.Ada to analyze all of the output from the polynomial benchmarks. |
| VAX_BENCHMARKS_COM_LINK | Calls other procedures to compile/link the benchmarks on the VAX Ada compiler. |
| VAX_COMPILATION_RUN | Calls Compilation_Benchmarks to compile/link the compilation benchmarks on the VAX Ada compiler. |
| VAX_INT_EXEC1_RUN | Runs integrated execution 1 on the VAX. |
| VAX_INT_EXEC2_RUN | Runs integrated execution 2 on the VAX. |
| VAX_INT_EXEC3_RUN | Runs integrated execution 3 on the VAX. |
| VAX_POLY_RUN | Runs the polynomial benchmarks on the VAX. |

## 3. COMPILING THE POLYNOMIAL AND INTEGRATED EXECUTION BENCHMARKS

The two classes of executable benchmarks in the Armonics Benchmark Suite must be compiled and linked prior to benchmarking. On VAX/VMS, this process is automatic and is accomplished by the VAX_Benchmarks_Com_Link command procedure provided with the Benchmark Suite. This command procedure establishes a process in the logical Compilation_Directory and then proceeds to call other Benchmark Suite command procedures to accomplish the various compilation and linkage editing tasks. The following command procedures are performed in order:

1. Compile_Benchmark_Support: compiles the CAMP and 11th Missile software used in benchmarking. This software contains the actual benchmarks (i.e., the CAMP parts selected as benchmarks) as well as necessary support code. After compilation, this software comprises a library of Ada units which provide a context for the subsequent compilation of the benchmark drivers.

2. Compile_Tools: compiles packages of benchmarking tools used by the drivers. These packages are fully portable and provide the drivers with necessary I/O routines and other utilities.

3. VAX_Analyze_Com_Link: compiles and links the tool, Analyze, used to analyze the output of the polynomial benchmarks. This tool is dependent on VMS and VAX Ada as explained in Section III. The Benchmark Suite program library dependency of this tool is limited to the package Benchmarking_Tools, compiled by the procedure, Compile_Tools, just discussed. This means that the analysis tool may be independently compiled on VAX/VMS and VAX Ada and then used to check the polynomial benchmark output from other systems.

4. Poly6_Com_Link and Poly9_Com_Link: compile and link the polynomial benchmark drivers. Two command procedures are used: one for the drivers using 6-digit Ada floating point numbers, and one for the drivers using 9-digit numbers. Thus, Ada systems which do not support the extended floating-point representations may still compile the lower-accuracy drivers without difficulty. It should be noted, however, that the Ada source code files of Poly9_Com_Link will not correctly compile unless those of Poly6_Com_Link have already been compiled. Two packages necessary to the polynomial benchmark drivers of both precisions are compiled in Poly6_Com_Link.

5. Int_Exec1_Com_Link, Int_Exec2_Com_Link, and Int_Exec3_Com_Link: compile and link the integrated execution benchmarks. Each of these command procedures compiles the support and drivers necessary to run the respective integrated execution benchmarks.

6. System_Com_Link: recompiles CAMP Polynomials support on the VAX then compiles and links the System Driver benchmarks. This driver uses the VAX Ada math library as a set of benchmarks. The Polynomials System_Functions LLCSC interfaces this driver to the math library. This can be of interest to users of VAX/VMS and VAX Ada who must use the VAX Ada "slide rule" functions, but who have to meet real-time constraints.

## 4. RUNNING THE EXECUTION BENCHMARKS

### a. Polynomial Benchmark Execution

Once compiled and linked, the polynomial benchmark drivers may be run to produce data. As has been discussed, these drivers send output to standard output which is generally the console. On most systems supporting file I/O, including VMS, the standard output can be redirected to files.

The command procedure VAX_Poly_Run is an example of running the polynomial benchmarks in the VMS environment. Standard input is redefined to permit the drivers to request their input from a file. This file, created automatically by VAX_Poly_Run at benchmark time, contains data to supply the benchmark drivers with the following:

- Compiler Name: the name of the compiler used to compile the polynomial drivers (becomes part of the output data).

- Host Name: the name of the compiler host machine (becomes part of the output data).

- Target Name: the name of the target machine of the compiler and the machine on which the benchmarks will run (becomes part of the output data).

- Number of timing iterations: the number of times that a driver must call a function in order to achieve a certain accuracy in calculating the time for a single call.

- Number of data iterations: the number of data values to use as arguments to a function of the driver. This defines the number of argument-result pairs produced as output for each benchmark of the driver.

Standard output, like standard input, is also redefined in the case of each benchmark driver to channel output to files. This permits the subsequent analysis of the output by the analysis program Analyze.

The analysis program is not portable from the VMS and VAX Ada environment due to use of the VAX Math_Lib. Thus, use of the program on other systems is prohibited unless modifications are made. The program may, however, be modified by interfacing it to another math library, as long as the output from new math library has greater than nine Ada digits of precision. This is necessary since the math library is used by the analysis program to check the results of the polynomial benchmarks, which use up to nine digits of accuracy.

Running the analysis program is trivial and is demonstrated by the VAX_Analyze_Poly com-

mand procedure. A user simply executes the analysis program, Analyze, and provides it with the name of a data file produced by running the polynomial benchmark drivers. The program prompts again to request the name of the file in which the analyzed output is to be placed. After the analysis of a file is complete the program starts over, requesting the name of the next input file. If no file name is provided, the program terminates.

It should be noted that, although the analysis program is non-portable, it may be used to analyze polynomial benchmark data from diverse systems. A user with access to VAX/VMS and VAX Ada may use the analysis program exclusively on that system to check the benchmark output from many other systems.

### b. Integrated Execution Benchmarks

Running the integrated execution benchmarks is similar to running the polynomial benchmarks. The command procedures VAX_Int_Exec1_Run, VAX_Int_Exec2_Run, and VAX_Int_Exec3_Run automatically execute the three integrated execution benchmark groups on VMS. These procedures provide the input data required by the drivers while the output of the drivers is trapped in log files by VMS.

Like the polynomial benchmark drivers, the integrated execution benchmark drivers use only standard I/O. The input data required by each of the drivers is as follows:

- Compiler Name: the name of the compiler used to compile the polynomial drivers (becomes part of the output data).
- Host Name: the name of the compiler host machine (becomes part of the output data).
- Target Name: the name of the target machine of the compiler and the machine on which the benchmarks will run (becomes part of the output data).
- Numbers of Timing Iterations: a series of numbers telling the driver how many times to execute corresponding benchmarks. Unlike the polynomial benchmarks, the different integrated execution benchmarks within a driver do not all have to be executed the same number of times. Also, overhead timing iterations vary from benchmark to benchmark. The command procedures which run the integrated execution benchmarks on VAX/VMS may be consulted for more details.

The output generated by running the integrated execution benchmarks consists of two types of data:

1. Result data, which represents the results of the calculations performed by the subprograms chosen as benchmarks and,
2. A table of timing data showing the time used for a single call to each benchmark subprogram.

Output data of the first type is to be used in checking the *correctness* of the data processing of a tested system. Such output should closely match the corresponding standard data supplied with the Benchmark Suite. The second type of data represents the *run-time efficiency* of the tested system and is expected to vary widely from system to system.

Although both kinds of data are produced with each run of an integrated execution benchmark driver, the correctness of the two types is mutually exclusive in a given run. A run which provides accurate run-time efficiency data is, by design, likely to produce poor data for correctness checking. The reverse is also true. For this reason, each integrated execution benchmark must be run twice, once for timing purposes and once to obtain data for comparison to supplied standard data.

When performing the timing run, the number of iterations for each benchmark subprogram (specified by the user at run-time) must be high in order to compensate for the generally low accuracy of the clock functions. Each subprogram will then be called many times, the time for one call being calculated by simple division. To aid the user, each benchmark driver reports the number of iterations necessary to obtain microsecond accuracy. Also, whatever number the user specifies, the resultant table of timings will show estimates of the accuracy actually obtained.

On the other hand, performing the benchmark run for correctness of data processing requires that the benchmark subprograms be executed only once. Thus, the user must specify that only one iteration be used for each subprogram. More than one call to a given subprogram can alter the output data, making any comparison to the standard invalid. This is due to the use of in-out parameters and occasional side effects in the benchmark subprograms. Results, in these cases, tend to accumulate changes from call to call as previously discussed.

# APPENDIX A

# ARMONICS BENCHMARK SUITE

This appendix presents a summary of the data which CAMP obtained from the Armonics Benchmark Suite. In some cases the data represents performance parameters of the selected CAMP parts as they operate on a 32-bit minicomputer. However, when possible, data reflecting the operation of the benchmarks in a Mil-Std-1750A microprocessor environment has been included.

The compilation benchmark data underscores some of the difficulties a software engineer may experience when selecting or applying an Ada compiler. It was found that many validated Ada compilers currently lack the ability to handle complex source code. The problem is essentially one of relative reliability: Some Ada compilers seem to work all of the time; most Ada compilers seem to work some of the time.

The polynomial benchmarks, which measure run-time parameters of Polynomials scientific functions, were executed successfully in both the 32-bit minicomputer and 1750A microprocessor environments. This supplied us with data enabling us to draw some useful conclusions about the CAMP parts, the Ada language, and the tested compiler/processor pairs. Finally, performance data from the integrated execution benchmarks serves to validate these benchmarks. At the time of this writing these benchmarks could not be run in any but the 32-bit environment due to errors in compilation to the 1750A target machine.

## 1. COMPILATION BENCHMARK DATA

The compilation benchmarks were used to test four separate Ada Compiler/Linker systems. One compiler, Compiler A, was self-targeted and served, because of its demonstrated reliability, as the validation compiler for the benchmarks. The other three compilers, B, C, and D, were recently validated cross-compilers to a 1750A target.

Compiler A succeeded in compiling all of the source code of the compilation benchmarks. It produced no warnings and no errors. The accompanying linker subsequently produced load modules with no difficulties. As a final step, the load modules were run on the host system to see if they would produce run-time errors. On this host, no errors occurred although this implies no guarantees about other systems.

Compiler B succeeded in compiling all of the source code correctly except the driver of the Kalman filter compilation benchmark, Compilation 3. Numerous warnings were issued in the course of compilation. The vast majority of these warnings concerned optimizations which could have been made in the Ada code but, for reasons of readability, were not. The compiler had performed an optimization that was not made by the programmer at the source code level. The warnings produced by Compiler B were justified with the exception of two concerning program semantics.

In compiling the Kalman filter driver, Compiler B evidently lost track of a necessary file. Object code was still generated but it was probably erroneous. Nevertheless, all three drivers were successfully linked, albeit with one warning. The linker of Compiler B produced the required load modules and did

not fail to note that the Kalman filter driver had compiled with errors. The load modules were next loaded into the MDAC-Huntington Beach Mil-Std-1750A Simulator and their sizes were recorded.

Compiler C compiled all of the support packages of the compilation benchmarks but failed to compile any of the three drivers. In all three cases, the compiler ended abnormally in a late phase of processing. For this reason, Compiler C's linker could not be fairly tested.

Compiler D had been validated very recently and appeared to be having many of the problems associated with any new compiler. It failed to compile even the support packages of the compilation benchmarks. After successfully compiling the first three Ada files, the compiler falsely diagnosed the fourth as having semantic errors. Continuing through the source code, the compiler found numerous other "errors" in the error-free code.

A summary of the data collected on Compilers A, B, and C is presented in Table A-1. Insufficient data was obtained from Compiler D to justify its inclusion in the table. It should be noted that the object code size data for Compiler A may be unrealistically small. The size mentioned in the table does not include any run-time system services which may be required.

TABLE A-1. COMPILATION BENCHMARK DATA

| COMPILER/ LINKER | SUCCESSFUL COMPILE? | SUCCESSFUL LINK? | TOTAL CPU TIME (secs.) | TOTAL OBJECT CODE SIZE |
|---|---|---|---|---|
| A | Yes | Yes | 10:56.56 | 62K bytes |
| B | Most | Yes | 22:42.33 | 122K bytes |
| C | No | NA | 30:00.00? | ? |

## 2. POLYNOMIAL BENCHMARK DATA

The polynomial benchmarks were used to test two subject systems. System A consisted of Compiler A, above, and the host/target system of that compiler. System B consisted of Compiler B and the MDAC Huntington Beach Mil-Std-1750A simulator, which simulates a 1750A bare machine. Running the benchmarks on System A produced performance data on the CAMP Polynomials package parts as they run on a 32-bit time-sharing minicomputer. System B produced data for the same parts as they run on a 20 MHz 1750A microprocessor. Compilers C and D, above, failed to compile the polynomial benchmarks.

For each function of the Polynomials package, size data was obtained on System B. It was felt that 1750A size data was relevant to armonics applications. Moreover, this data was readily available in the linkage map files produced by the linker of System B. On the other hand, size data on the 32-bit system was less meaningful and was excluded. System A makes extensive use of built-in service routines which are not counted in load size; on a bare machine, system services are part of the load module or run-time system and are counted — a fact which casts doubt on the validity of code size estimates. Table A-2 gives the size data for functions of the Polynomials package on System B.

Time-consumption and mathematical precision data on the polynomial functions was collected for both systems A and B. This data is summarized in Figures A-1 to A-12. Each graph plots the execution

## TABLE A-2. SYSTEM B POLYNOMIALS SIZES

| TLCSC Name / LLCSC Name / Unit Name | Size (words) Hex. | Size (words) Dec. |
|---|---|---|
| Chebyshev | | |
| Radian_Operations | | |
| Sin_R_5Term | 5D | 93 |
| Degree_Operations | | |
| Sin_D_5Term | 5D | 93 |
| Semicircle_Operations | | |
| Sin_S_5Term | 5A | 90 |
| Cody_Waite | | |
| Natural_Log | | |
| Nat_Log | 59 | 89 |
| Base_N | | |
| Log_N | 12 | 18 |
| Continued_Fractions | | |
| Radian_Operations | | |
| Tan_R | 31 | 49 |
| Arctan_R | 36 | 54 |
| Fike | | |
| Semicircle_Operations | | |
| Arcsin_S_4Term | 60 | 96 |
| Arcsin_S_5Term | 64 | 100 |
| Arcsin_S_6Term | 68 | 104 |
| Arccos_S_4Term | 62 | 98 |
| Arccos_S_5Term | 66 | 102 |
| Arccos_S_6Term | 6A | 106 |
| Hart | | |
| Radian_Operations | | |
| Cos_R_5Term | 52 | 82 |
| Degree_Operations | | |
| Cos_D_5Term | 51 | 81 |
| Hastings | | |
| Radian_Operations | | |
| Sin_R_4Term | 36 | 54 |
| Sin_R_5Term | 3A | 58 |
| Cos_R_4Term | 3D | 61 |
| Cos_R_5Term | 41 | 65 |
| Tan_R_4Term | 25 | 37 |
| Tan_R_5Term | 25 | 37 |
| Arctan_R_6Term | 26 | 38 |
| Arctan_R_7Term | 2A | 42 |
| Arctan_R_8Term | 2E | 46 |
| Mod_Arctan_R_6Term | 4C | 76 |
| Mod_Arctan_R_7Term | 50 | 80 |
| Mod_Arctan_R_8Term | 54 | 84 |
| Degree_Operations | | |
| Sin_D_4Term | 36 | 54 |
| Sin_D_5Term | 3A | 58 |
| Cos_D_4Term | 3D | 61 |
| Cos_D_5Term | 41 | 65 |
| Tan_D_4Term | 23 | 35 |
| Tan_D_5Term | 23 | 35 |

| TLCSC Name / LLCSC Name / Unit Name | Size (words) Hex. | Size (words) Dec. |
|---|---|---|
| Mod_Newton_Raphson | | |
| Sqrt | 61 | 97 |
| Newton_Raphson | | |
| Sqrt | 6C | 108 |
| Taylor_Series | | |
| Radian_Operations | | |
| Sin_R_4Term | 34 | 52 |
| Sin_R_5Term | 37 | 55 |
| Sin_R_6Term | 3A | 58 |
| Sin_R_7Term | 3D | 61 |
| Sin_R_8Term | 40 | 64 |
| Cos_R_4Term | 4F | 79 |
| Cos_R_5Term | 52 | 82 |
| Cos_R_6Term | 55 | 85 |
| Cos_R_7Term | 58 | 88 |
| Cos_R_8Term | 5B | 91 |
| Tan_R_8Term | 2B | 43 |
| Arcsin_R_5Term | 22 | 34 |
| Arcsin_R_6Term | 26 | 38 |
| Arcsin_R_7Term | 2A | 42 |
| Arcsin_R_8Term | 2E | 46 |
| Arcos_R_5Term | 29 | 41 |
| Arcos_R_6Term | 2D | 45 |
| Arcos_R_7Term | 31 | 49 |
| Arcos_R_8Term | 35 | 53 |
| Arctan_R_4Term | 31 | 49 |
| Arctan_R_5Term | 35 | 53 |
| Arctan_R_6Term | 39 | 57 |
| Arctan_R_7Term | 3D | 61 |
| Arctan_R_8Term | 41 | 65 |
| Alt_Arctan_R_4Term | 1E | 30 |
| Alt_Arctan_R_5Term | 22 | 34 |
| Alt_Arctan_R_6Term | 26 | 38 |
| Alt_Arctan_R_7Term | 2A | 42 |
| Alt_Arctan_R_8Term | 2E | 46 |
| Mod_Sin_R_4Term | 6B | 107 |
| Mod_Sin_R_5Term | 73 | 115 |
| Mod_Sin_R_6Term | 7B | 123 |
| Mod_Sin_R_7Term | 83 | 131 |
| Mod_Sin_R_8Term | 8B | 139 |
| Mod_Cos_R_4Term | 76 | 118 |
| Mod_Cos_R_5Term | 7E | 126 |
| Mod_Cos_R_6Term | 86 | 134 |
| Mod_Cos_R_7Term | 8E | 142 |
| Mod_Cos_R_8Term | 96 | 150 |
| Mod_Tan_R_4Term | 14 | 20 |
| Mod_Tan_R_5Term | 14 | 20 |
| Mod_Tan_R_6Term | 14 | 20 |
| Mod_Tan_R_7Term | 14 | 20 |
| Mod_Tan_R_8Term | 14 | 20 |

| TLCSC Name / LLCSC Name / Unit Name | Size (words) Hex. | Size (words) Dec. |
|---|---|---|
| Taylor Series (cont.) | | |
| Degree_Operations | | |
| Sin_D_5Term | 8C | 140 |
| Sin_D_6Term | 4C | 76 |
| Sin_D_7Term | 50 | 80 |
| Sin_D_8Term | 54 | 84 |
| Cos_D_5Term | 9D | 157 |
| Cos_D_6Term | 53 | 83 |
| Cos_D_7Term | 56 | 86 |
| Cos_D_8Term | 59 | 89 |
| Tan_D_8Term | 36 | 54 |
| Mod_Sin_D_4Term | 76 | 118 |
| Mod_Sin_D_5Term | 7E | 126 |
| Mod_Sin_D_6Term | 86 | 134 |
| Mod_Sin_D_7Term | 8E | 142 |
| Mod_Sin_D_8Term | 96 | 150 |
| Mod_Cos_D_4Term | 74 | 116 |
| Mod_Cos_D_5Term | 7C | 124 |
| Mod_Cos_D_6Term | 84 | 132 |
| Mod_Cos_D_7Term | 8C | 140 |
| Mod_Cos_D_8Term | 94 | 148 |
| Mod_Tan_D_4Term | 14 | 20 |
| Mod_Tan_D_5Term | 14 | 20 |
| Mod_Tan_D_6Term | 14 | 20 |
| Mod_Tan_D_7Term | 14 | 20 |
| Mod_Tan_D_8Term | 14 | 20 |

time of a function against the absolute precision of that function's results. Both the time and precision data are taken over the function argument domains listed at the bottom of each figure.

The domain specifications are of particular importance since a given function, apparently superior in terms of performance, may nevertheless operate correctly only over a small domain. This is, for example, true in the case of the radian arctangent benchmarks (Figures A-6 and A-12) where the "Alt Taylor" method appears to be the best performer. However, referring to the domain specification, it becomes apparent that the "Alt Taylor" method only provides the indicated performance over the domain [0.0, 0.4]. Other functions provide a more acceptable domain at a slightly higher throughput cost.

The absence of separate data for six and nine digit instantiations in the figures based on System B is due to the fact that compiler B always uses 1750A extended precision (approximately 9 decimal digits) to represent any generic floating-point object. Identical object code is used for each instantiation of a

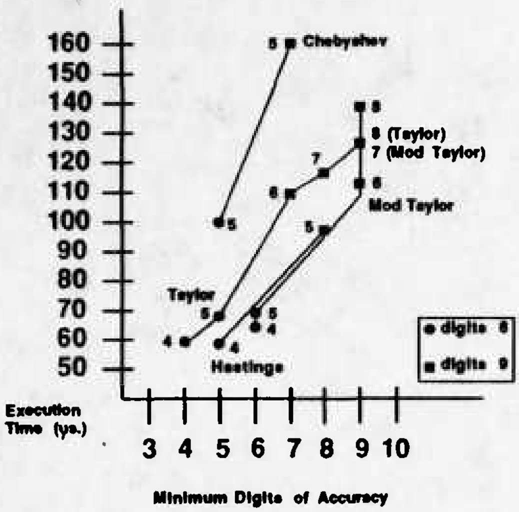
generic floating-point subprogram and, indeed, compiler B shares one object code instruction section among all instantiations of a given generic. The use of this "single copy" method implies that the running times of different instantiations of the same generic subprogram will be identical, regardless of the precision of the floating-point variables. Thus, the nine-digit worst case data applies for both six and nine-digit instantiations.

## 3. INTEGRATED EXECUTION BENCHMARK DATA

The integrated execution benchmarks, which integrate numerous CAMP parts, were run on the 32-bit minicomputer (System A above, Tables A-3, A-4, and A-5).

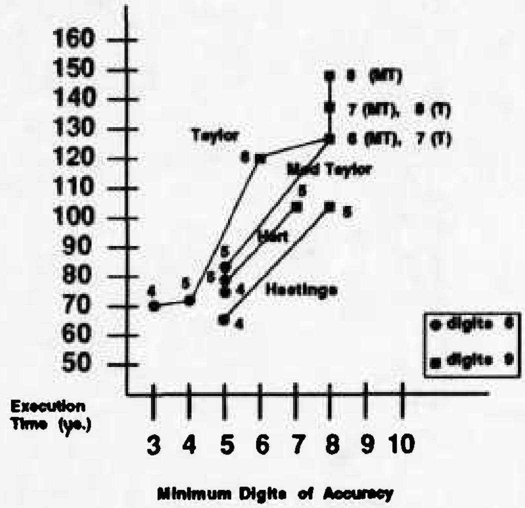
Standard output data for these benchmarks is supplied in the form of files accompanying the benchmark suite. This data can be used to verify that a compiler and target machine combination produce correct output for the benchmarks. The data is not reproduced here because it is quite lengthy and is not formatted for inclusion in a document.

Time-consumption data on the integrated execution benchmarks was automatically collected at run-time by the benchmark drivers. This data is presented in Tables A-3, A-4, and A-5.



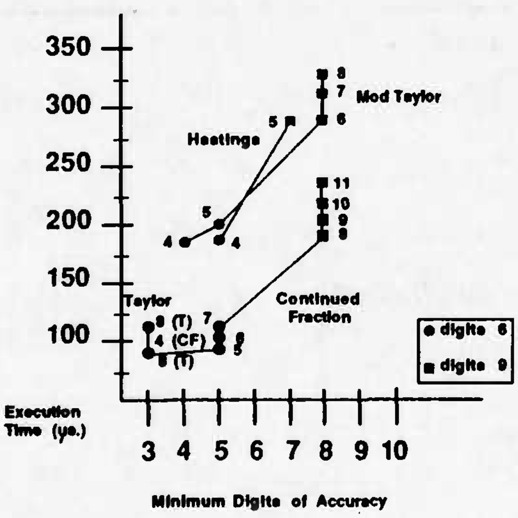

Numbers shown indicate the number of terms used in the polynomial expansion. The function domain over which this data applies is [-pi/2, pi/2].

**Figure A-1.** Radian Sine on System A



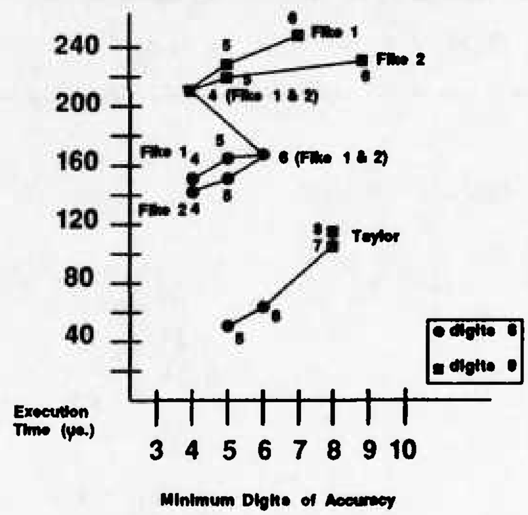

Numbers shown indicate the number of terms used in the polynomial expansion. The function domain over which this data applies is [0, pi].

**Figure A-2.** Radian Cosine on System A




Numbers shown indicate the number of terms used in the polynomial expansion. The function domain over which this data applies is [-1, 1].

**Figure A-3.** Radian Tangent on System A

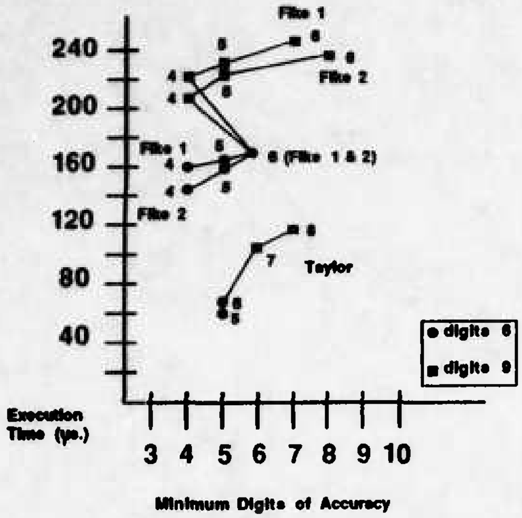



Numbers shown indicate the number of terms used in the polynomial expansion. The function domains over which these data apply are as follows:

Taylor Radian: [-0.44, 0.44]
Fike 1 Semicircle: [-0.6, 0.6]
Fike 2 Semicircle: [-1.0, 1.0]

Where Fike 1 uses the Newton-Raphson square root and Fike 2 uses the Modified Newton-Raphson square root.

**Figure A-4.** Arcsine on System A

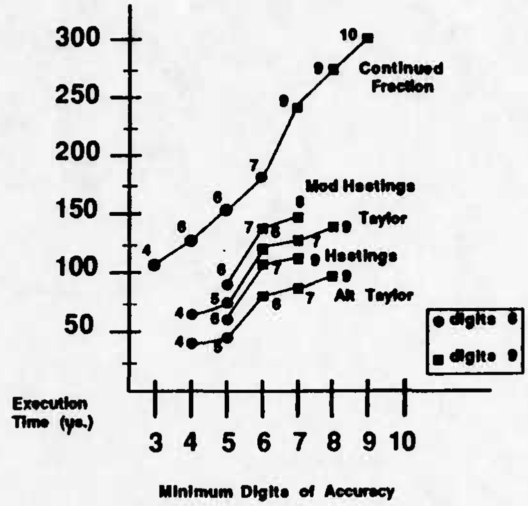



Numbers shown indicate the number of terms used in the polynomial expansion. The function domains over which these data apply are as follows:

Taylor Radian: [-0.46, 0.46]
Fike 1 Semicircle: [-0.6, 0.6]
Fike 2 Semicircle: [-1.0, 1.0]

Where Fike 1 uses the Newton-Raphson square root and Fike 2 uses the Modified Newton-Raphson square root.

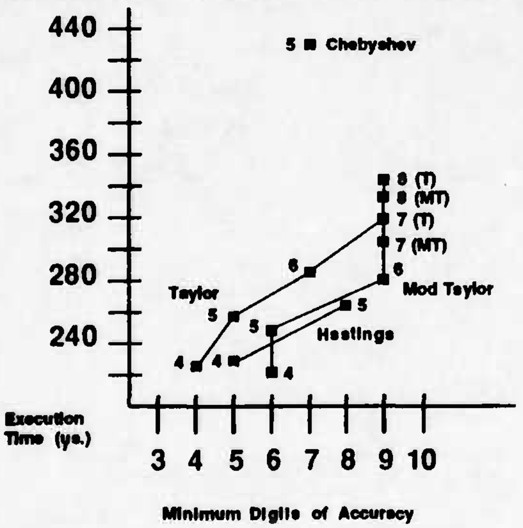
**Figure A-5.** Arccosine on System A




Numbers shown indicate the number of terms used in the polynomial expansion. The function domains over which these data apply are as follows:

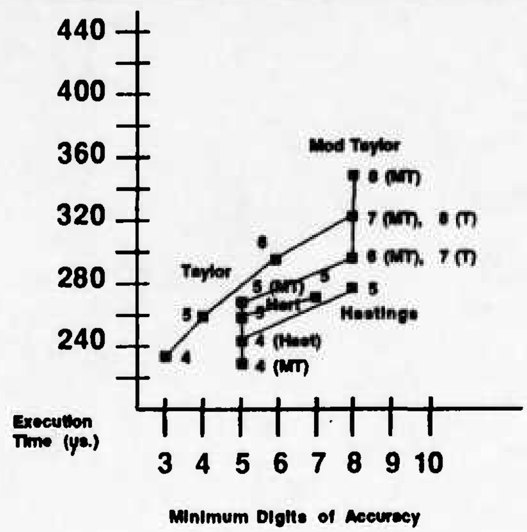
Taylor: [2.63, 80.0]
Alt Taylor: [0.0, 0.4]
Hastings: [-1.0, 1.0]
Mod Hastings: [0.0, 80.0]
Continued Fraction: [0.0, 0.7167]

**Figure A-6.** Radian Arctangent on System A



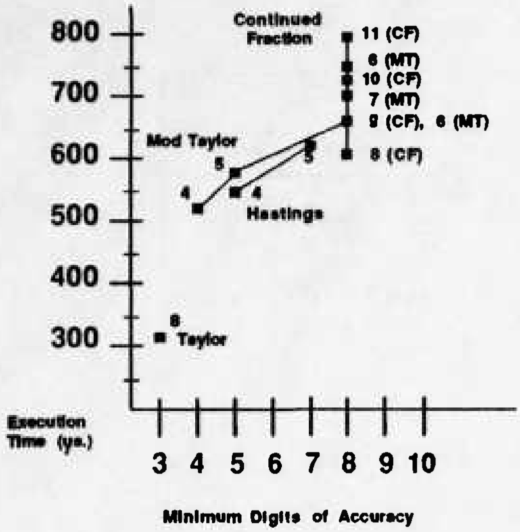

Numbers shown indicate the number of terms used in the polynomial expansion. The function domain over which this data applies is [-pi/2, pi/2].

**Figure A-7.** Radian Sine on System B



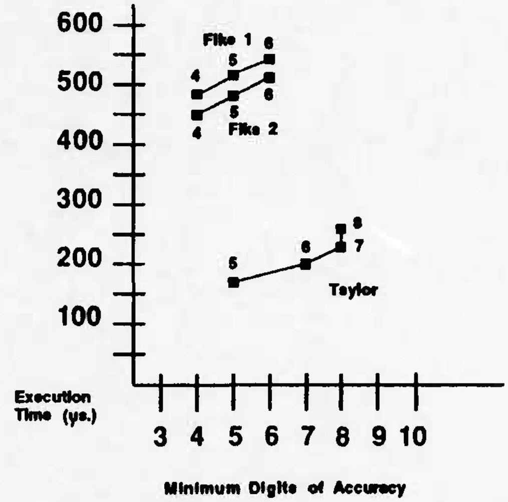

Numbers shown indicate the number of terms used in the polynomial expansion. The function domain over which this data applies is [0, pi].

**Figure A-8.** Radian Cosine on System B




Numbers shown indicate the number of terms used in the polynomial expansion. The function domain over which this data applies is [-1, 1].

Figure A-9. Radian Tangent on System B

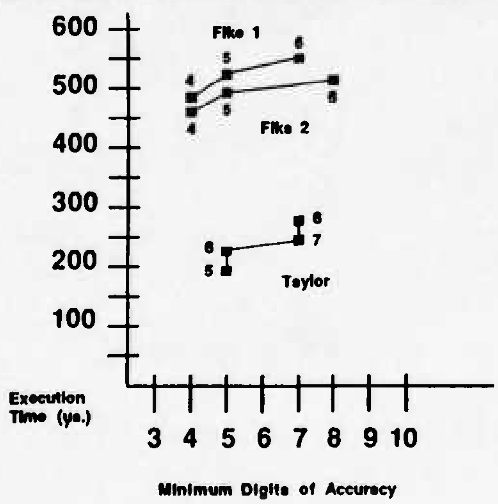



Numbers shown indicate the number of terms used in the polynomial expansion. The function domains over which these data apply are as follows:

Taylor Radian: [-0.44, 0.44]
Fike 1 Semicircle: [-0.6, 0.6]
Fike 2 Semicircle: [-1.0, 1.0]

Where Fike 1 uses the Newton-Raphson square root and Fike 2 uses the Modified Newton-Raphson square root.

Figure A-10. Arcsine on System B

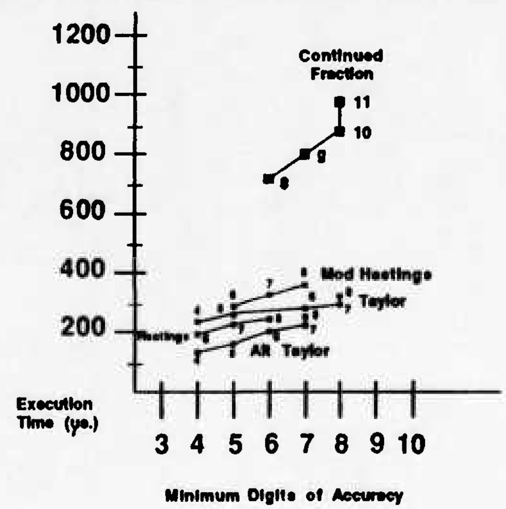



Numbers shown indicate the number of terms used in the polynomial expansion. The function domains over which these data apply are as follows:

Taylor Radian: [-0.46, 0.46]
Fike 1 Semicircle: [-0.6, 0.6]
Fike 2 Semicircle: [-1.0, 1.0]

Where Fike 1 uses the Newton-Raphson square root and Fike 2 uses the Modified Newton-Raphson square root.

Figure A-11. Arccosine on System B




Numbers shown indicate the number of terms used in the polynomial expansion. The function domains over which these data apply are as follows:

| | |
|---|---|
| Taylor: | [2.63, 50.0] |
| Alt Taylor: | [0.0, 0.4] |
| Hastings: | [-1.0, 1.0] |
| Mod Hastings: | [0.0, 50.0] |
| Continued Fraction: | [0.0, 0.7167] |

Figure A-12. Radian Arctangent on System B

**TABLE A-3. TIMING OF INTEGRATED EXECUTION 1**

| Integrated Execution 1 on VAX | | |
|---|---|---|
| TLCSC Name (some names abbreviated)<br>LLCSC Name<br>Unit Name | Time (microsecs) | |
| | Per Call | Variation |
| Waypoint_Steering (P661) | | |
| Compute_Turn_Angle_And_Direction | 391.0 | 0 |
| Compute_Turning_And_Nonturning_Dist | 173.0 | 0 |
| Distance_To_Current_Waypoint | 409.0 | 0 |
| Steering_Vector_Operations_W_Arcsin | | |
| Initialize | 5210.0 | 5 |
| Update | 2623.0 | 10 |
| Turn_Test_Operations | | |
| Stop_Test | 62.0 | 2 |
| Start_Test | 61.0 | 0 |
| Signal_Processing (P686) | | |
| Absolute_Limiter | | |
| Limit | 43.0 | 0 |
| Upper_Lower_Limiter | | |
| Update_Limits | 15.0 | 0 |
| Limits | 57.0 | 0 |

## TABLE A-4. TIMING OF INTEGRATED EXECUTION 2

| Integrated Execution 2 on VAX | | |
|---|---|---|
| TLCSC Name (some names abbreviated)<br>LLCSC Name<br>Unit Name | Time (microsecs) | |
| | Per Call | Variation |
| Common_Navigation_Parts (P001) | | |
| Update_Velocity | | |
| Reinitialize | 34.0 | 2 |
| Current_Velocity<br>Update | 51.0 | 2 |
| Compute_Ground_Velocity | 509.0 | 2 |
| Compute_Gravitational_Accel_Sin_Lat_In | 332.0 | 2 |
| Wander_Azimuth_Navigation_Parts (P002) | | |
| Earth_Rotation_Rate | | |
| Compute | 338.0 | 2 |
| Earth_Relative_Navigation_Rotat_Rates | | |
| Compute | 414.0 | 0 |
| Total_Platform_Rotation_Rate | 151.0 | 0 |
| Compute_Latitude_Using_Two_Val_Arctan | 623.0 | 0 |
| Compute_Longitude_Using_Two_Val_Arctan | 430.0 | 0 |
| Compute_East_Velocity_With_Sin_Cos | 231.0 | 2 |
| Compute_North_Velocity_With_Sin_Cos | 232.0 | 2 |
| Compute_Coriolis_Acceleration | 769.0 | 2 |
| Compute_Wand_Azim_Angle_Two_Val_Arctan | 432.0 | 0 |
| Compute_Curvatures | 820.0 | 0 |
| Direction_Cosine_Matrix (P644) | | |
| CNE_Operations | | |
| Compute_First_Row_CNE_From_Ortho | 199.0 | 0 |
| CNE_Initialized_From_Reference | 1647.0 | 2 |
| Perform_Rect_Integration_Of_CNE | 664.0 | 0 |
| Reorthonormalize_CNE | 1698.0 | 2 |
| Aligned_CNE_Matrix | 1178.0 | 2 |
| General_Vector_Matrix_Algebra (P682) | | |
| Matrix_Matrix_Multiply_Restricted | 3861.0 | 0 |
| General_Purpose_Math_Parts (P687) | | |
| Accumulator | | |
| Accumulate | 19.0 | 2 |

## TABLE A-5. TIMING OF INTEGRATED EXECUTION 3

| Integrated Execution 3 on VAX | | |
|---|---|---|
| TLCSC Name (some names abbreviated) / LLCSC Name / Unit Name | Time (microsecs) | |
| | Per Call | Variation |
| Kalman_Filter_Common_Parts (P651) | | |
| State_Transition_And_Proc_Noise_Mat_Mgr | | |
| Initialize | 1603.0 | 1 |
| Propagate | 187290.0 | 10 |
| Get_Current | 113.0 | 1 |
| Propagated_Phi | 119.0 | 1 |
| Error_Covariance_Matrix_Manager | | |
| Initialize | 69.0 | 1 |
| Propagate | 149540.0 | 10 |
| P | 119.0 | 1 |
| State_Transition_Matrix_Manager | | |
| Initialize | 1547.0 | 1 |
| Propagated_Phi | 117.0 | 1 |
| Propagate | 28073.0 | 10 |
| Kalman_Filter_Compact_H_Parts (P652) | | |
| Compute_Kalman_Gains | 10978.0 | 2 |
| Update_Error_Covariance_Matrix | 16267.0 | 2 |
| Update_State_Vector | 6360.0 | 2 |
| Seq_Update_Cov_Matrix_And_State_Vector | | |
| Update | 67897.0 | 2 |
| Kalman_Update | | |
| Update | 233355.0 | 2 |
| Update_Error_Cov_Matrix_General_Form | 73222.0 | 2 |
| Kalman_Filter_Complicated_H_Parts (P653) | | |
| Compute_Kalman_Gains | 24687.0 | 1 |
| Update_Error_Covariance_Matrix | 60033.0 | 2 |
| Update_State_Vector | 12756.0 | 1 |
| Seq_Update_Cov_Matrix_And_State_Vector | | |
| Update | 192150.0 | 10 |
| Kalman_Update | | |
| Update | 361139.0 | 10 |
| Update_Error_Cov_Matrix_General_Form | 215098.0 | 10 |

# APPENDIX B

# ADA SOURCE CODE INVENTORY

The following tables comprise an inventory of all Ada source code used in the CAMP Armonics Benchmark Suite. In addition, the tables provide a cross-reference from the development name of a file to the ANSI name assigned to that file for transportation to other operating systems.

## TABLE B-1. ADA SOURCE CODE INVENTORY

(1 of 10)

| Armonics Benchmark Inventory and Cross-Reference | |
|---|---|
| **Development Name** | **ANSI Name** |
| **CAMP Source Code** | |
| 001_000_COMMON_NAV_.ADA | A001000.ADA |
| 001_001_COMMON_NAV.ADA | A001001.ADA |
| 001_100_ALTITUDE_INTEGRATION.ADA | A001100.ADA |
| 001_200_COMP_GROUND_VEL.ADA | A001200.ADA |
| 001_300_COMP_GRAV_ACCEL_LAT_IN.ADA | A001300.ADA |
| 001_400_COMP_GRAV_ACCEL_SIN_LAT_IN.ADA | A001400.ADA |
| 001_500_COMP_HEADING.ADA | A001500.ADA |
| 001_600_UPDATE_VELOCITY.ADA | A001600.ADA |
| 001_700_SCALAR_VELOCITY.ADA | A001700.ADA |
| 001_800_COMP_ROTATION_INCR.ADA | A001800.ADA |
| 002_000_WA_NAV_.ADA | A002000.ADA |
| 002_001_WA_NAV.ADA | A002001.ADA |
| 002_100_EAST_VELOCITY.ADA | A002100.ADA |
| 002_200_NORTH_VELOCITY.ADA | A002200.ADA |
| 002_300_EARTH_REL_HOR_VELS.ADA | A002300.ADA |
| 002_400_TOTAL_ANGULAR_VEL.ADA | A002400.ADA |
| 002_500_CORIOLIS_ACCEL.ADA | A002500.ADA |
| 002_600_CORIOLIS_ACCEL_TOT_RATES.ADA | A002600.ADA |
| 002_700_RAD_OF_CURV.ADA | A002700.ADA |
| 002_800_TOT_PLATFORM_ROT_RATE.ADA | A002800.ADA |
| 002_900_EARTH_ROT_RATE.ADA | A002900.ADA |
| 002_A00_EARTH_REL_ROT_RATE.ADA | A002A00.ADA |
| 002_B00_LATITUDE.ADA | A002B00.ADA |
| 002_C00_LATITUDE_USING_ATAN.ADA | A002C00.ADA |
| 002_D00_LONGITUDE.ADA | A002D00.ADA |
| 002_E00_WANDER_ANGLE.ADA | A002E00.ADA |
| 002_F00_EAST_VEL_SIN_COS.ADA | A002F00.ADA |
| 002_G00_NORTH_VEL_SIN_COS.ADA | A002G00.ADA |
| 002_H00_EARTH_REL_HOR_VELS_SIN_COS.ADA | A002H00.ADA |
| 002_I00_LATITUDE_USING_ATAN2.ADA | A002I00.ADA |
| 002_J00_LONGITUDE_USING_ATAN2.ADA | A002J00.ADA |
| 002_K00_WANDER_ANGLE_USING_ATAN2.ADA | A002K00.ADA |
| 611_000_WGS72_METRIC_.ADA | A611000.ADA |
| 613_000_WGS72_UNITLESS_.ADA | A613000.ADA |
| 614_000_CONVERSION_FACTORS_.ADA | A614000.ADA |
| 615_000_UNIVERSAL_CONSTANTS_.ADA | A615000.ADA |
| 621_000_BDT_.ADA | A621000.ADA |

**TABLE B-1. ADA SOURCE CODE INVENTORY (2 OF 10)**

| Armonics Benchmark Inventory and Cross-Reference | |
|---|---|
| Development Name | ANSI Name |
| 621_001_BDT.ADA | A621001.ADA |
| 622_000_KDT_.ADA | A622000.ADA |
| 622_001_KDT.ADA | A622001.ADA |
| 634_000_CLOCK_HANDLER_.ADA | A634000.ADA |
| 634_001_CLOCK_HANDLER.ADA | A634001.ADA |
| 644_000_DCM_.ADA | A644000.ADA |
| 644_001_DCM.ADA | A644001.ADA |
| 651_000_KALMAN_COMMON_.ADA | A651000.ADA |
| 651_001_KALMAN_COMMON.ADA | A651001.ADA |
| 651_100_PHI_Q_MANAGER.ADA | A651100.ADA |
| 651_200_P_MANAGER.ADA | A651200.ADA |
| 651_300_PHI_MANAGER.ADA | A651300.ADA |
| 652_000_KALMAN_COMPACT_.ADA | A652000.ADA |
| 652_001_KALMAN_COMPACT.ADA | A652001.ADA |
| 652_100_CKG.ADA | A652100.ADA |
| 652_200_UPDATE_P.ADA | A652200.ADA |
| 652_300_UPDATE_X.ADA | A652300.ADA |
| 652_400_UPDATE_P_AND_X.ADA | A652400.ADA |
| 652_500_KALMAN_UPDATE.ADA | A652500.ADA |
| 652_600_UPDATE_P_GENERAL.ADA | A652600.ADA |
| 653_000_KALMAN_COMPLICATED_.ADA | A653000.ADA |
| 653_001_KALMAN_COMPLICATED.ADA | A653001.ADA |
| 653_100_CKG.ADA | A653100.ADA |
| 653_200_UPDATE_P.ADA | A653200.ADA |
| 653_300_UPDATE_X.ADA | A653300.ADA |
| 653_400_UPDATE_P_AND_X.ADA | A653400.ADA |
| 653_500_KALMAN_UPDATE.ADA | A653500.ADA |
| 653_600_UPDATE_P_GENERAL.ADA | A653600.ADA |
| 661_000_WAYPOINT_STEERING_.ADA | A661000.ADA |
| 661_001_WAYPOINT_STEERING.ADA | A661001.ADA |
| 661_300_STEERING_VECTOR_OPNS.ADA | A661300.ADA |
| 661_310_INITIALIZE.ADA | A661310.ADA |
| 661_320_UPDATE.ADA | A661320.ADA |
| 661_400_TURN_ANGLE_AND_DIRECTION.ADA | A661400.ADA |
| 661_500_CRSSTRK_AND_HDG_ERR_OPNS.ADA | A661500.ADA |
| 661_510_COMP_WHEN_TURNING.ADA | A661510.ADA |
| 661_520_COMP_WHEN_NOT_TURNING.ADA | A661520.ADA |
| 661_530_COMPUTE.ADA | A661530.ADA |
| 661_600_DIST_TO_CURR_WAYPOINT.ADA | A661600.ADA |
| 661_700_COMP_TURN_NONTURN_DIST.ADA | A661700.ADA |

## TABLE B-1. ADA SOURCE CODE INVENTORY (3 OF 10)

| Armonics Benchmark Inventory and Cross-Reference | |
|---|---|
| **Development Name** | **ANSI Name** |
| 661_800_TURN_TEST_OPNS.ADA | A661800.ADA |
| 661_810_STOP_TEST.ADA | A661810.ADA |
| 661_820_START_TEST.ADA | A661820.ADA |
| 661_900_STEERING_VECTOR_OPNS_ARCSIN.ADA | A661900.ADA |
| 661_A00_DIST_TO_CURR_WAYPOINT_ARCSIN.ADA | A661A00.ADA |
| 681_000_C_ALGEBRA_.ADA | A681000.ADA |
| 681_001_C_ALGEBRA.ADA | A681001.ADA |
| 681_200_MATRIX_OPNS.ADA | A681200.ADA |
| 681_230_SET_TO_IDENTITY_MATRIX.ADA | A681230.ADA |
| 681_240_SET_TO_ZERO_MATRIX.ADA | A681240.ADA |
| 681_400_MATRIX_SCALAR_OPNS.ADA | A681400.ADA |
| 681_500_CROSS_PRODUCT.ADA | A681500.ADA |
| 681_600_MATRIX_VECTOR_MULT.ADA | A681600.ADA |
| 681_700_MATRIX_MATRIX_MULT.ADA | A681700.ADA |
| 682_000_GENERAL_ALGEBRA_.ADA | A682000.ADA |
| 682_001_GENERAL_ALGEBRA.ADA | A682001.ADA |
| 682_100_VECTOR_OPNS_UC.ADA | A682100.ADA |
| 682_200_MATRIX_OPNS_UC.ADA | A682200.ADA |
| 682_300_DYN_SPARSE_MATRIX_UC.ADA | A682300.ADA |
| 682_400_SYMM_HALF_STORAGE_MATRIX.ADA | A682400.ADA |
| 682_500_SYMM_FULL_STORAGE_MATRIX_UC.ADA | A682500.ADA |
| 682_600_DIAGONAL_MATRIX.ADA | A682600.ADA |
| 682_700_VECTOR_SCALAR_OPNS_UC.ADA | A682700.ADA |
| 682_800_MATRIX_SCALAR_OPNS_UC.ADA | A682800.ADA |
| 682_900_DIAG_MATRIX_SCALAR_OPNS.ADA | A682900.ADA |
| 682_A00_MATRIX_MATRIX_MULT_UR.ADA | A682A00.ADA |
| 682_B00_MATRIX_VECTOR_MULT_UR.ADA | A682B00.ADA |
| 682_C00_VECTOR_VECTOR_TRANS_MULT_UR.ADA | A682C00.ADA |
| 682_D00_MATRIX_MATRIX_TRANS_MULT_UR.ADA | A682D00.ADA |
| 682_E00_DOT_PRODUCT_OPN_UR.ADA | A682E00.ADA |
| 682_F00_DIAG_FULL_MATRIX_ADD_UR.ADA | A682F00.ADA |
| 682_G00_VECTOR_OPNS_C.ADA | A682G00.ADA |
| 682_H00_MATRIX_OPNS_C.ADA | A682H00.ADA |
| 682_J00_DYN_SPARSE_MATRIX_C.ADA | A682J00.ADA |
| 682_K00_SYMM_FULL_STORAGE_MATRIX_C.ADA | A682K00.ADA |
| 682_L00_VECTOR_SCALAR_OPNS_C.ADA | A682L00.ADA |
| 682_M00_MATRIX_SCALAR_OPNS_C.ADA | A682M00.ADA |
| 682_N00_MATRIX_MATRIX_MULT_R.ADA | A682N00.ADA |
| 682_P00_MATRIX_VECTOR_MULT_R.ADA | A682P00.ADA |
| 682_Q00_VECTOR_VECTOR_TRANS_MULT_R.ADA | A682Q00.ADA |

TABLE B-1. ADA SOURCE CODE INVENTORY (4 OF 10)

| Armonics Benchmark Inventory and Cross-Reference | |
|---|---|
| Development Name | ANSI Name |
| 682_R00_MATRIX_MATRIX_TRANS_MULT_R.ADA | A682R00.ADA |
| 682_S00_DOT_PRODUCT_OPN_R.ADA | A682S00.ADA |
| 682_T00_DIAG_FULL_MATRIX_ADD_R.ADA | A682T00.ADA |
| 682_U00_VECTOR_MATRIX_MULT_UR.ADA | A682U00.ADA |
| 682_V00_VECTOR_MATRIX_MULT_R.ADA | A682V00.ADA |
| 682_W00_ABA_TRANS_DSP_MATRIX_SQ_MATRIX.ADA | A682W00.ADA |
| 682_X00_ABA_TRANS_VECTOR_SQ_MATRIX.ADA | A682X00.ADA |
| 682_Y00_ABA_TRANS_VECTOR_SCALAR.ADA | A682Y00.ADA |
| 682_Z00_COL_MATRIX_OPNS.ADA | A682Z00.ADA |
| 683_000_STANDARD_TRIG_.ADA | A683000.ADA |
| 683_001_STDTRIG_SYSFNS.ADA | A683001.ADA |
| 684_000_GEOMETRIC_.ADA | A684000.ADA |
| 684_001_GEOMETRIC.ADA | A684001.ADA |
| 684_100_UNIT_RADIAL_VECTOR.ADA | A684100.ADA |
| 684_200_UNIT_NL_VECTOR.ADA | A684200.ADA |
| 684_300_SEG_UNIT_NL_VECTOR.ADA | A684300.ADA |
| 684_400_GREAT_CIRCLE_ARC_LENGTH.ADA | A684400.ADA |
| 684_500_SEG_UNIT_NL_VECTOR_ARCSIN.ADA | A684500.ADA |
| 686_000_SIGNAL_.ADA | A686000.ADA |
| 686_001_SIGNAL.ADA | A686001.ADA |
| 686_100_UL_LIMITER.ADA | A686100.ADA |
| 686_200_U_LIMITER.ADA | A686200.ADA |
| 686_300_L_LIMITER.ADA | A686300.ADA |
| 686_400_ABS_LIMITER.ADA | A686400.ADA |
| 686_500_ABS_LIMITER_W_FLAG.ADA | A686500.ADA |
| 686_600_FIRST_ORDER_FILTER.ADA | A686600.ADA |
| 686_700_TUSTIN_LAG_FILTER.ADA | A686700.ADA |
| 686_800_TUSTIN_LEAD_LAG_FILTER.ADA | A686800.ADA |
| 686_900_SECOND_ORDER_FILTER.ADA | A686900.ADA |
| 686_A00_TUSTIN_INTEGRATOR_W_LIMIT.ADA | A686A00.ADA |
| 686_B00_TUSTIN_INT_W_ASYM_LIMIT.ADA | A686B00.ADA |
| 687_000_GP_MATH_.ADA | A687000.ADA |
| 687_001_GP_MATH.ADA | A687001.ADA |
| 687_100_LOOKUP_EVEN.ADA | A687100.ADA |
| 687_200_LOOKUP_UNEVEN.ADA | A687200.ADA |
| 687_300_INCREMENTOR.ADA | A687300.ADA |
| 687_400_DECREMENTOR.ADA | A687400.ADA |
| 687_500_RUN_AVG.ADA | A687500.ADA |
| 687_600_ACCUM.ADA | A687600.ADA |
| 687_700_CHANGE_ACCUM.ADA | A687700.ADA |

TABLE B-1. ADA SOURCE CODE INVENTORY (5 OF 10)

| Armonics Benchmark Inventory and Cross-Reference | |
|---|---|
| Development Name | ANSI Name |
| 687_800_CHANGE_CALC.ADA | A687800.ADA |
| 687_900_INTEGRATOR.ADA | A687900.ADA |
| 687_A00_INTERPOLATE.ADA | A687A00.ADA |
| 687_D00_RSOS.ADA | A687D00.ADA |
| 687_E00_SIGN.ADA | A687E00.ADA |
| 687_F00_MEAN_VAL.ADA | A687F00.ADA |
| 687_G00_MAD.ADA | A687G00.ADA |
| 687_H00_LOOKUP_TWOWAY.ADA | A687H00.ADA |
| 688_001_POLYNOMIALS.ADA | A688001.ADA |
| 688_200_CHEBYSHEV.ADA | A688200.ADA |
| 688_210_RADIAN_OPERATIONS.ADA | A688210.ADA |
| 688_220_DEGREE_OPERATIONS.ADA | A688220.ADA |
| 688_230_SEMICIRCLE_OPERATIONS.ADA | A688230.ADA |
| 688_300_FIKE.ADA | A688300.ADA |
| 688_310_SEMICIRCLE_OPERATIONS.ADA | A688310.ADA |
| 688_400_HART.ADA | A688400.ADA |
| 688_410_RADIAN_OPERATIONS.ADA | A688410.ADA |
| 688_420_DEGREE_OPERATIONS.ADA | A688420.ADA |
| 688_500_HASTINGS.ADA | A688500.ADA |
| 688_510_RADIAN_OPERATIONS.ADA | A688510.ADA |
| 688_520_DEGREE_OPERATIONS.ADA | A688520.ADA |
| 688_800_MOD_NEWTON_RAPHSON.ADA | A688800.ADA |
| 688_900_NEWTON_RAPHSON.ADA | A688900.ADA |
| 688_A00_TAYLOR_SERIES.ADA | A688A00.ADA |
| 688_A10_RADIAN_OPERATIONS.ADA | A688A10.ADA |
| 688_A20_DEGREE_OPERATIONS.ADA | A688A20.ADA |
| 688_A40_NATURAL_LOG.ADA | A688A40.ADA |
| 688_A50_BASE_LOG.ADA | A688A50.ADA |
| 688_B00_GENL_POLYNOMIAL.ADA | A688B00.ADA |
| 688_C00_SYSTEM_FUNCTIONS.ADA | A688C00.ADA |
| 688_C10_RADIAN_OPNS.ADA | A688C10.ADA |
| 688_C20_SEMICIRCLE_OPNS.ADA | A688C20.ADA |
| 688_C30_DEGREE_OPNS.ADA | A688C30.ADA |
| 688_C40_SQUARE_ROOT.ADA | A688C40.ADA |
| 688_C50_BASE_10.ADA | A688C50.ADA |
| 688_C60_BASE_N.ADA | A688C60.ADA |
| 688_D00_CONTINUED_FRACTIONS.ADA | A688D00.ADA |
| 688_D10_RADIAN_OPERATIONS.ADA | A688D10.ADA |
| 688_E00_CODY_WAITE.ADA | A688E00.ADA |
| 688_E40_NATURAL_LOG.ADA | A688E40.ADA |

**TABLE B-1. ADA SOURCE CODE INVENTORY (6 OF 10)**

| Armonics Benchmark Inventory and Cross-Reference | |
|---|---|
| **Development Name** | **ANSI Name** |
| 688_E50_BASE_N.ADA | A688E50.ADA |
| 688_F00_REDUCTION.ADA | A688F00.ADA |
| 851_000_UNIT_CONVERSION_.ADA | A851000.ADA |
| 851_001_UNIT_CONVERSION.ADA | A851001.ADA |
| 890_000_QUATERNION_.ADA | A890000.ADA |
| 890_001_QUATERNION.ADA | A890001.ADA |
| 890_100_EULER.ADA | A890100.ADA |
| 890_200_NORMALIZED.ADA | A890200.ADA |
| **11th Missile Code (some modified)** | |
| BARO_ALT_FOR_KF_TESTS.ADA | MBAFKFT.ADA |
| BARO_TEST_DRIVER.ADA | MBROTES.ADA |
| DATA_RETRIEVAL_FOR_GUIDOPNS_TEST.ADA | MDTARET.ADA |
| DO_SUM_BARO_ALTIMETER_FOR_BIAS_TEST.ADA | MDSUMBA.ADA |
| DUMMY_AM.ADA | MDMMYAM.ADA |
| DUMMY_DO_SUM_BARO.ADA | MDMMYDO.ADA |
| DUMMY_INITIALIZE_NAVIGATOR.ADA | MDMMYIN.ADA |
| DUMMY_VELOCITY_COMPUTATIONS.ADA | MDMMYVE.ADA |
| EARTH_TO_BODY_TRANSFORM.ADA | MERTHTO.ADA |
| ENVIRONMENT_FOR_KF_TESTS.ADA | MEVIRON.ADA |
| EXECUTE_NAVIGATOR.ADA | MXNAVIG.ADA |
| EXECUTE_NAVIGATOR_TEST.ADA | MEXECUT.ADA |
| EX_NAV_KALMAN_FILTER_STUB.ADA | MEXNAVK.ADA |
| GUID_COMPUTER_FOR_GUIDOPNS_TEST.ADA | MGUIDCO.ADA |
| INCORPORATE_KALMAN_CORR.ADA | MINCORP.ADA |
| INTERNAL_BUS_BROADCAST_FOR_KF_TESTS.ADA | MINTERN.ADA |
| ISA_FOR_KF_TESTS.ADA | MISAFOR.ADA |
| KALMAN_FILTER_STUB.ADA | MKALMAN.ADA |
| M007_100_GUIDANCE_OPNS.ADA | M007100.ADA |
| M007_110_PROCESSOR_MODIFIED.ADA | M007110.ADA |
| M007_111_PRINCIPAL_VALUE.ADA | M007111.ADA |
| M007_112_PERFORM_INIT.ADA | M007112.ADA |
| M007_113_WAYPT_CNTRL_OPNS.ADA | M007113.ADA |
| M007_114_FLIGHT_CONTROL.ADA | M007114.ADA |
| M007_115_FIRST_ORDER.ADA | M007115.ADA |
| M012_000_GUIDANCE_DATA_TYPES_.ADA | M012000.ADA |
| M012_001_GUIDANCE_DATA_TYPES.ADA | M012001.ADA |
| M013_000_MISSION_DATA_.ADA | M013000.ADA |
| M014_000_NAV_COMPUTER_DATA_TYPES_.ADA | M014000.ADA |
| M014_001_NAV_COMPUTER_DATA_TYPES.ADA | M014001.ADA |
| M015_001_NAVIGATION_OPERATIONS.ADA | M015001.ADA |

**TABLE B-1. ADA SOURCE CODE INVENTORY (7 OF 10)**

| Armonics Benchmark Inventory and Cross-Reference | |
|---|---|
| **Development Name** | **ANSI Name** |
| M015_0200_EXECUTE_NAVIGATOR.ADA | M015020.ADA |
| M015_0900_SLAVE_CNE.ADA | M015090.ADA |
| M015_0C00_BARO_LOOP_COMPUTATIONS.ADA | M0150C0.ADA |
| M015_0H00_NAV_OPS_TEST_CODE.ADA | M0150H0.ADA |
| M017_000_ALIGNMENT_MEASUREMENTS_.ADA | M017000.ADA |
| M018_000_NAV_SYSTEM_.ADA | M018000.ADA |
| M019_000_KALMAN_TYPES_.ADA | M019000.ADA |
| M019_001_KALMAN_TYPES.ADA | M019001.ADA |
| M019_0100_F_OPERATIONS.ADA | M019010.ADA |
| M019_0200_PHI_OPERATIONS.ADA | M019020.ADA |
| M019_0800_ACTIVE_KHPO.ADA | M019080.ADA |
| M019_0900_PASSIVE_KHPO.ADA | M019090.ADA |
| M019_0A00_DOPPLER_KHPO.ADA | M0190A0.ADA |
| M021_000_KALMAN_FILTER_.ADA | M021000.ADA |
| M022_000_ENVIRONMENT_.ADA | M022000.ADA |
| M024_000_H_ROW_.ADA | M024000.ADA |
| M024_001_H_ROW.ADA | M024001.ADA |
| M611_000_WGS72_METRIC_.ADA | M611000.ADA |
| M612_000_WGS72_ENGINEERING_.ADA | M612000.ADA |
| MEASUREMENTS_FOR_KF_TESTS.ADA | MMEASUR.ADA |
| MESSAGE_MANAGER_FOR_GUIDOPNS_TEST.ADA | MMESSAG.ADA |
| MISSION_DATA_FOR_GUIDOPNS_TEST.ADA | MMISSIO.ADA |
| NAVIGATION_OPERATIONS_.ADA | MNAVIGA.ADA |
| NAV_SYSTEM_STUB.ADA | MNAVSYS.ADA |
| OCU_FOR_KF_TESTS.ADA | MOCUFOR.ADA |
| SCP_FOR_KF_TESTS.ADA | MSCPFOR.ADA |
| TLM_FOR_KF_TESTS.ADA | MTLMFOR.ADA |
| VELOCITY_COMPUTATIONS.ADA | MVELOCI.ADA |
| VELOCITY_COMPUTATIONS_TEST.ADA | MVELOCT.ADA |
| VEL_TEST_DRIVER.ADA | MVELTES.ADA |
| WANDER_ANGLE_COMPUTATIONS.ADA | MWANDER.ADA |
| Compilation Benchmark Source Code | |
| 10_WGS72U_.ADA | C10WGS7.ADA |
| 20_NPNAV_.ADA | C20NPNA.ADA |
| 21_NPNAV.ADA | C21NPNA.ADA |
| 30_KFCOMMON_.ADA | C30KFCO.ADA |
| 31_KFCOMMON.ADA | C31KFCO.ADA |
| 40_KFCOMPLICATED_.ADA | C40KFCO.ADA |
| 41_KFCOMPLICATED.ADA | C41KFCO.ADA |
| 50_POLY_.ADA | C50POLY.ADA |

**TABLE B-1. ADA SOURCE CODE INVENTORY (8 OF 10)**

| Amonics Benchmark Inventory and Cross-Reference | |
|---|---|
| **Development Name** | **ANSI Name** |
| 51_POLY.ADA | C51POLY.ADA |
| 60_GVMA_.ADA | C60GVMA.ADA |
| 61_GVMA.ADA | C61GVMA.ADA |
| 70_GPMATH_.ADA | C70GPMA.ADA |
| 71_GPMATH.ADA | C71GPMA.ADA |
| 80_CVMA_.ADA | C80CVMA.ADA |
| 81_CVMA.ADA | C81CVMA.ADA |
| 90_STDTRIG_.ADA | C90STDT.ADA |
| 91_STDTRIG.ADA | C91STDT.ADA |
| A0_GEO_.ADA | CA0GEOX.ADA |
| A1_GEO.ADA | CA1GEOX.ADA |
| B0_UNIVCONST_.ADA | CB0UNIV.ADA |
| C0_CONVFACTORS_.ADA | CC0CONV.ADA |
| D0_BDT_.ADA | CD0BDTX.ADA |
| D1_BDT.ADA | CD1BDTX.ADA |
| E0_WPS_.ADA | CE0WPSX.ADA |
| E1_WPS.ADA | CE1WPSX.ADA |
| F0_WGS72_.ADA | CF0WGS7.ADA |
| G0_KDT_.ADA | CG0KDTX.ADA |
| G1_KDT.ADA | CG1KDTX.ADA |
| Z1_NP_TDRVR.ADA | CZ1NPTD.ADA |
| Z2_WPS_TDRVR.ADA | CZ2WPST.ADA |
| Z3_KF_TDRVR.ADA | CZ3KFTD.ADA |
| **Original Benchmark Source Code** | |
| 683A_000_STANDARD_TRIG_.ADA | A683A00.ADA |
| 683A_001_STDTRIG_FIKE_HASTINGS.ADA | A683A00.ADA |
| 683B_000_STANDARD_TRIG_.ADA | A683B00.ADA |
| 683B_001_STDTRIG_FIKE_HASTINGS.ADA | A683B00.ADA |
| 683_002_STD_TRG_NOSYS.ADA | A683002.ADA |
| 687_C01_NEWTON_SQRT.ADA | A687C01.ADA |
| 688_000_POLYNOMIALS_.ADA | A688000.ADA |
| 688_310_SEMICIRCLE_OPERATIONS.ADA | A688310.ADA |
| ANALYZE.ADA | BANALYZ.ADA |
| BENCHMARKING_TOOLS.ADA | BBNMARK.ADA |
| BENCHMARKING_TOOLS_.ADA | BBNCHMA.ADA |
| BENCHMARK_CONTENTS.ADA | BBNCHMR.ADA |
| BENCHMARK_CONTENTS_.ADA | BBNCHMK.ADA |
| CHEBYSHEV6_DRIVER.ADA | BCHEBY6.ADA |
| CHEBYSHEV9_DRIVER.ADA | BCHEBY9.ADA |
| CODY6_DRIVER.ADA | BCDY6DR.ADA |

TABLE B-1. ADA SOURCE CODE INVENTORY (9 OF 10)

| Armonics Benchmark Inventory and Cross-Reference | |
|---|---|
| Development Name | ANSI Name |
| CODY9_DRIVER.ADA | BCDY9DR.ADA |
| CONTINUED6_DRIVER.ADA | BCNT6DR.ADA |
| CONTINUED9_DRIVER.ADA | BCNT9DR.ADA |
| CONTINUED_FRACTION_BENCHMARK.ADA | BCNTFRA.ADA |
| CONTINUED_FRACTION_BENCHMARK_.ADA | BCNTFRC.ADA |
| CPU_CLOCK.ADA | BCPUCLO.ADA |
| FIKE6_DRIVER.ADA | BFIKE6D.ADA |
| FIKE9_DRIVER.ADA | BFIKE9D.ADA |
| HART6_DRIVER.ADA | BHART6D.ADA |
| HART9_DRIVER.ADA | BHART9D.ADA |
| HASTINGS6_DRIVER.ADA | BHAST6D.ADA |
| HASTINGS9_DRIVER.ADA | BHAST9D.ADA |
| INT_BENCHMARKING_TOOLS.ADA | BINTBEN.ADA |
| INT_BENCHMARKING_TOOLS_.ADA | BINTBNC.ADA |
| KALMAN_COMMON_TEST.ADA | BKALMNC.ADA |
| KALMAN_COMMON_TEST_.ADA | BKALMAN.ADA |
| KALMAN_COMPACT_DRIVER.ADA | BKLMANC.ADA |
| KALMAN_COMPACT_TEST.ADA | BKLMNCO.ADA |
| KALMAN_COMPACT_TEST_.ADA | BKLMCOM.ADA |
| KALMAN_COMPLICATED_DRIVER.ADA | BKLMNCM.ADA |
| KALMAN_COMPLICATED_TEST.ADA | BKLNCOM.ADA |
| KALMAN_COMPLICATED_TEST_.ADA | BKLMCOM.ADA |
| MATRIX_OUTPUT.ADA | BMATRIX.ADA |
| MATRIX_OUTPUT_.ADA | BMTRIXO.ADA |
| NEWTON6_DRIVER.ADA | BNWTN6D.ADA |
| NEWTON9_DRIVER.ADA | BNEWTN9.ADA |
| POLYNOMIALS_NO_SYS_FUNC.ADA | BPLYNOM.ADA |
| POLYNOMIALS_NO_SYS_FUNC_.ADA | BPOLYNO.ADA |
| POLYNOMIAL_BENCHMARK.ADA | BPOLYNM.ADA |
| POLYNOMIAL_BENCHMARK_.ADA | BPOLNOM.ADA |
| REDUCE_SIM_LOG.ADA | BREDUCE.ADA |
| SYSTEM_DRIVER.ADA | BSYSTEM.ADA |
| TAYLOR6_DEGREE_DRIVER.ADA | BTYLOR6.ADA |
| TAYLOR6_RADIAN_DRIVER.ADA | BTAYLR6.ADA |
| TAYLOR9_DEGREE_DRIVER.ADA | BTYLOR9.ADA |
| TAYLOR9_RADIAN_DRIVER.ADA | BTAYLR9.ADA |
| Benchmark VAX/VMS Command Procedures | |
| ACT_COMPILATION_RUN.COM | JACTCOM.COM |
| COMPILATION_BENCHMARKS.COM | JCMPILA.COM |
| COMPILE_BENCHMARK_SUPPORT.COM | JCOMPIL.COM |

TABLE B-1. ADA SOURCE CODE INVENTORY (CONCLUDED)

| Armonics Benchmark Inventory and Cross-Reference | |
|---|---|
| Development Name | ANSI Name |
| COMPILE_TOOLS.COM | JCMPLTO.COM |
| INT_EXEC1_COM_LINK.COM | JINT1CM.COM |
| INT_EXEC2_COM_LINK.COM | JINT2CM.COM |
| INT_EXEC3_COM_LINK.COM | JINT3CM.COM |
| MODIFIED_POLY6_COM_LINK.COM | JMDPOL6.COM |
| MODIFIED_POLY9_COM_LINK.COM | JMDPOL9.COM |
| POLY6_COM_LINK.COM | JPLY6CM.COM |
| POLY9_COM_LINK.COM | JPLY9CM.COM |
| SYSTEM_COM_LINK.COM | JSYSCML.COM |
| TLD_BENCHMARKS_COM_LINK.COM | JTLDBCO.COM |
| TLD_COMPILATION_RUN.COM | JTLDCOM.COM |
| VAX_ANALYZE_COM_LINK.COM | JVAXANL.COM |
| VAX_ANALYZE_POLY.COM | JVAXALY.COM |
| VAX_BENCHMARKS_COM_LINK.COM | JVAXBSC.COM |
| VAX_COMPILATION_RUN.COM | JVAXCOM.COM |
| VAX_INT_EXEC1_RUN.COM | JVAXI1R.COM |
| VAX_INT_EXEC2_RUN.COM | JVAXI2R.COM |
| VAX_INT_EXEC3_RUN.COM | JVAXI3R.COM |
| VAX_POLY_RUN.COM | JVAXPRU.COM |
| ANSI/Development Name Conversion | |
| ANSI2DV.COM | ANSI2DV.COM |
| DV2ANSI.COM | DV2ANSI.COM |
| Standard Output Data Files | |
| VAX_INT_EXEC1_RUN.DAT | DVXIE1R.DAT |
| VAX_INT_EXEC2_RUN.DAT | DVXIE2R.DAT |
| VAX_INT_EXEC3_RUN.DAT | DVXIE3R.DAT |
| HART6_DRIVER.ANA | DHART6D.ANA |
| HART6_DRIVER.DAT | DHART6D.DAT |

INITIAL DISTRIBUTION LIST

| | |
|---|---|
| GTE GOVERNMENT SYS CORP | 1 |
| ADVANCED DIGITAL SYSTEMS | 1 |
| AFATL/FXG | 4 |
| MILITARY COMPUTER SYSTEMS | 1 |
| LOCKHEED/0/62-81, B/563, F15 | 1 |
| HUGHES/FULLERTON | 1 |
| UNISYS/MS-E1D08 | 1 |
| WESTINGHOUSE/BALTIMORE | 1 |
| AFWAL/AAAS-2 | 1 |
| BOOZ-ALLEN & HAMILTON, INC | 1 |
| BOEING AEROSPACE COMPANY/MS 8H-09 | 1 |
| BOEING AEROSPACE CO | 1 |
| AD/YGE | 1 |
| SOFTWARE PRODUCTIVITY CONSORTIUM | 5 |
| ARMY CECOM/AMSEL-COM-IA | 1 |
| NAVAL TRAINING SYS CENTER/CODE 251 | 1 |
| SCIENCE APPLICATIONS INTL CORP | 1 |
| RAYTHEON/MSL SYS DIVISION | 1 |
| CALSPAN | 1 |
| KAMAN SCIENCES CORPORATION | 1 |
| NAVAL RESEARCH LAB/CODE 5595 | 1 |
| CARNEGIE MELLON UNIV/SEI/SHOLOM | 1 |
| COLEMAN RESEARCH CORP | 1 |
| COLSA, INC | 1 |
| CONTROL DATA CORPORATION | 1 |
| WINTEC | 1 |
| CONTROL DATA/DEPT 1855 | 1 |
| DACS/RADC/COED | 1 |
| RAYTHEON/EQPT DIV | 1 |
| BMO/ACD | 1 |
| DDC-I, INC | 1 |
| ENGINEERING & ECONOMICS RESEARCH/ DIV OFFICE | 1 |
| BDM CORP | 1 |
| AFATL/FXG/EVERS | 1 |
| ESD/SYW-JPMO | 1 |
| FORD AEROSPACE & COMM CORP/MS H04 | 1 |
| UNIV OF COLORADO #202 | 1 |
| ANALYTICS | 1 |
| AFWAL/FIGL | 1 |
| WESTINGHOUSE ELECTRIC CORP/MS 5220 | 1 |
| GENERAL DYNAMICS/MZ W2-5530 | 1 |
| HONEYWELL INC | 1 |
| TAMSCO | 1 |
| STARS | 1 |
| FORD AEROSPACE/MS 2/206 | 1 |
| GRUMMAN HOUSTON CORPORATION | 1 |
| NAVAL AVIONICS CENTER/NAC-825 | 1 |
| NASA JOHNSON SPACE CENTER/EH/GHG | 1 |
| BOEING AEROSPACE/MS-8Y97 | 1 |
| HARRIS CORPORATION/GISD | 1 |
| CARNEGIE MELLON UNIV/ SOFTWARE ENGINEERING INST | 1 |
| NOAA/ERL/R/E/AL4 | 1 |
| INTERMETRICS, INC/G. RENTH | 1 |
| INTERMETRICS, INC/D.P. SMITH | 1 |
| FORD AEROSPACE/WEST DEVEL DIV | 1 |
| AD/ENE | 1 |
| ROCKWELL/MS-GA21 | 1 |
| GRUMMAN CORP/MS D-31-237 | 1 |
| INSTITUTE OF DEFENSE ANALYSIS | 1 |
| TELEDYNE BROWN/MS 178 | 1 |
| USAF/TAWC/SCAM | 1 |
| BOEING AEROSPACE CO/D. LINDBERG | 1 |
| LOGICON | 1 |
| EASTMAN KODAK/DEPT 47 | 1 |
| SYSTEMS CONTROL TECH, INC | 1 |
| E-SYSTEMS/GARLAND DIV | 1 |
| AFWAL/AAAF | 1 |
| MARTIN DEVELOPMENT | 1 |
| MA COMPUTER ASSOCIATES INC | 1 |
| IBM FEDERAL SYS DIV/MC 3206C | 1 |
| MCDONNELL DOUGLAS/INCO, INC | 1 |
| UNITED TECH, ADVANCED SYS | 1 |
| MCDONNELL AIRCRAFT CO/DEPT 300 | 1 |
| WESTINGHOUSE ELEC/MS 432 | 1 |
| MHP FU-TECH, INC | 1 |
| ITT AVIONICS | 1 |
| COSMIC/UNIV OF GA | 1 |
| NAVAL OCEAN SYS CENTER/CODE 423 | 1 |
| NAVAL WEAPONS CTR/CODE 3922 | 1 |
| ODYSSEY RESEARCH ASSOCIATES, INC | 1 |
| USA ELEC PROVING GRD/STEEP MT-DA | 1 |
| PATHFINDER SYS | 1 |
| BDM CORPORATION | 1 |
| PERCEPTRONICS, INC | 1 |
| PHOENIX INTERNATIONAL | 1 |
| MCDONNELL DOUGLAS ASTRO CO | 1 |
| GTE LABORATORY/RUBEN PRIETO-DIAZ | 1 |
| PROPRIETARY SOFTWARE SYSTEMS | 1 |
| ADVANCED TECHNOLOGY | 8 |
| STANFORD TELECOMMUNICATIONS, INC | 1 |
| RATIONAL | 1 |
| LOCKHEED MISSILES & SPACE CO | 1 |
| HERCULES DEFENSE ELEC SYS | 1 |
| AEROSPACE CORP | 1 |
| ROGERS ENGINEERING & ASSOCIATES | 1 |
| ADASOFT INC | 1 |
| ESD/XRSE | 1 |
| SANDERS/MER 24-1212 | 1 |
| CSC/ERIC SCHACHT | 1 |
| COMPUTER TECH ASSOCIATES, INC | 1 |

INITIAL DISTRIBUTION LIST (CONCLUDED)

| | |
|---|---|
| SCIENCE APPLICATIONS INTER CORP | 1 |
| HQ CASE/CBRC | 1 |
| GOULD INC/CSD | 1 |
| HQ AFSPACECOM/LKWD/STOP 32 | 1 |
| SVERDRUP/EGLIN | 1 |
| HONEYWELL INC/CLEARWATER | 1 |
| TECHNOLOGY SERVICE CORP | 1 |
| AEROSPACE/LOS ANGELES | 1 |
| SOFTWARE ARCHITECTURE & ENGIN | 1 |
| LORAL SYSTEMS GROUP/D/476-C2E | 1 |
| NADC/CODE 7033 | 1 |
| UNISYS/PAOLA RESEARCH CTR | 1 |
| SIRIUS INC | 1 |
| GENERAL RESEARCH CORP | 1 |
| SOFTECH, INC/R.L. ZALKAN | 1 |
| SOFTECH, INC/R.B. QUANRUD | 1 |
| SOFTWARE CERTIFICATION INS | 1 |
| SOFTWARE CONSULTING SPECIALIST | 1 |
| SOFTWARE PRODUCTIVITY SOLUTIONS, INC | 1 |
| STAR-GLO INDUSTRIES INC | 1 |
| NADC/CODE 50C | 1 |
| WESTINGHOUSE/BALTIMORE | 1 |
| MITRE CORPORATION | 1 |
| SYSCON CORP/I. WEBER | 1 |
| SYSCON CORP/C. MORSE | 1 |
| SYSCON CORP/T. GROBICKI | 1 |
| AEROSPACE CORPORATION/M-8-026 | 1 |
| TEXTRON DEFENSE SYSTEMS | 1 |
| GENERAL DYNAMICS/MZ 1774 | 1 |
| TIBURON SYSTEMS, INC | 1 |
| TRW DEFENSE SYS GROUP | 1 |
| NASA SPACE STATION | 1 |
| BALLISTIC MSL DEF ADVANCED/ TECHNOLOGY CENTER | 1 |
| IBM CORPORATION/FSD | 1 |
| VISTA CONTROLS CORPORATION | 1 |
| VITRO CORPORATION | 1 |
| NAVAL RESEARCH LABORATORY/CODE 5150 | 1 |
| CACI, INC | 1 |
| AFSC/PLR | 5 |
| DIRECTOR ADA JOINT PROGRAM OFFICE | 1 |
| MCDONNELL DOUGLAS ASTRONAUTICS/ E 434/106/2/MS22 | 7 |
| SDIO/S/PI | 1 |
| ADVANCED SOFTWARE TECH SPECIALTIES | 1 |
| DTIC-DDAC | 2 |
| AFCSA/SAMI | 1 |
| AUL/LSE | 1 |
| FTD/SDNF | 1 |
| AFWAL/FIES/SURVIAC | 1 |
| HQ USAFE/INATW | 1 |
| AFATL/CC | 1 |
| AFATL/CA | 1 |
| AFATL/DOIL | 2 |
| 6575 SCHOOL SQUADRON | 1 |
| IITRI | 1 |

# SUPPLEMENTARY

# INFORMATION

DEPARTMENT OF THE AIR FORCE
WRIGHT LABORATORY (AFSC)
EGLIN AIR FORCE BASE, FLORIDA, 32542-5434

ERRATA
AD-B129570

REPLY TO ATTN OF: MNOI

13 Feb 92

SUBJECT: Removal of Distribution Statement and Export-Control Warning Notices

TO: Defense Technical Information Center
ATTN: DTIC/HAR (Mr William Bush)
Bldg 5, Cameron Station
Alexandria, VA 22304-6145

1. The following technical reports have been approved for public release by the local Public Affairs Office (copy attached).

| | Technical Report Number | AD Number |
|---|---|---|
| 1. | 88-18-Vol-4 | ADB 120 251 |
| 2. | 88-18-Vol-5 | ADB 120 252 |
| 3. | 88-18-Vol-6 | ADB 120 253 |
| 4. | 88-25-Vol-1 | ADB 120 309 |
| 5. | 88-25-Vol-2 | ADB 120 310 |
| 6. | 88-62-Vol-1 | ADB 129 568 |
| 7. | 88-62-Vol-2 | ADB 129 569 |
| 8. | 88-62-Vol-3 | ADB 129-570 |
| 9. | 85-93-Vol-1 | ADB 102-654 |
| 10. | 85-93-Vol-2 | ADB 102-655 |
| 11. | 85-93-Vol-3 | ADB 102-656 |
| 12. | 88-18-Vol-1 | ADB 120 248 |
| 13. | 88-18-Vol-2 | ADB 120 249 |
| 14. | 88-18-Vol-7 | ADB 120 254 |
| 15. | 88-18-Vol-8 | ADB 120 255 |
| 16. | 88-18-Vol-9 | ADB 120 256 |
| 17. | 88-18-Vol-10 | ADB 120 257 * |
| 18. | 88-18-Vol-11 | ADB 120 258 |
| 19. | 88-18-Vol-12 | ADB 120 259 |

2. If you have any questions regarding this request call me at DSN 872-4620.

Lynn S. Wargo
LYNN S. WARGO
Chief, Scientific and Technical
Information Branch

1 Atch
AFDTC/PA Ltr, dtd 30 Jan 92

ERRATA

**DEPARTMENT OF THE AIR FORCE**
**HEADQUARTERS AIR FORCE DEVELOPMENT TEST CENTER (AFSC)**
**EGLIN AIR FORCE BASE, FLORIDA 32542-5000**

REPLY TO
ATTN OF: PA (Jim Swinson, 882-3931)

30 January 1992

SUBJECT: Clearance for Public Release

TO: WL/MNA

The following technical reports have been reviewed and are approved for public release: AFATL-TR-88-18 (Volumes 1 & 2), AFATL-TR-88-18 (Volumes 4 thru 12), AFATL-TR-88-25 (Volumes 1 & 2), AFATL-TR-88-62 (Volumes 1 thru 3) and AFATL-TR-85-93 (Volumes 1 thru 3).

Virginia N. Pribyla

VIRGINIA N. PRIBYLA, Lt Col, USAF
Chief of Public Affairs

AFDTC/PA 92-039